DIRECTIONS

177596 *Issue* 2

SPEEDOMAX® XL RECORDER

600 SERIES

LEEDS & NORTHRUP

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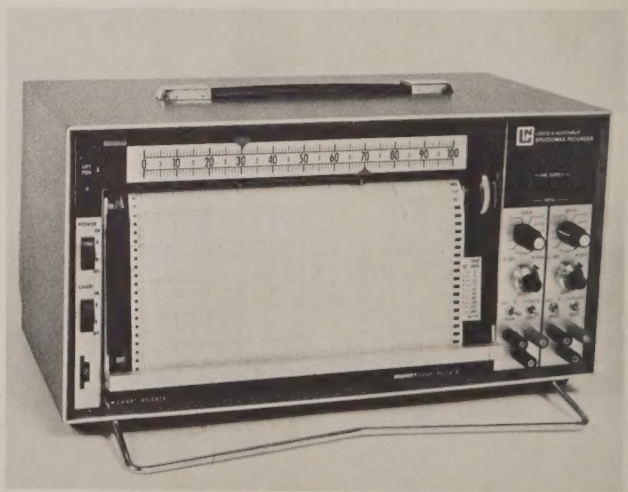
INTRODUCTION

The Speedomax XL Series 600 Recorder is a potentiometric-type, null-balance instrument, having high normal- and common-mode voltage rejection capabilities. It can be supplied as a one- or two-pen recorder.

As a two-pen recorder, it can simultaneously measure and record two functions on a moving 10-inch (nominal) wide chart. Response time for each pen is 1/3 second full scale. A 1-second response time for each pen is available as an option. On the two-pen recorder, the records are 1/8" apart on the time axis, each with full chart-span travel.

Recorders can be supplied with single or dual chart speeds, or up to a maximum of 10 speeds using an electronic speed changer. For single or dual chart speeds, a wide variation in speeds can be specified and additions or modifications of speeds can readily be carried out.

The measuring circuits are for emf type measurements only. But thermocouple measurements can be accommodated by means of a reference junction module supplied separately. The measuring circuits make use of a plug-in module which utilizes a plug-in span card for fixed spans, or a continuously adjustable AZAR (Adjustable Zero-Adjustable Range) circuit for variable spans. Spans cover ranges from 100 microvolts (μV) to 100 volts (V).



SPEEDOMAX XL RECORDER
LOW PROFILE-600 SERIES

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SPEEDOMAX XL RECORDER

600 SERIES

PART I INSTALLATION AND OPERATION

Section A–INSTALLATION

UNPACKING

General—Remove the instrument, Fig. A1, from its packing case, and remove any shipping ties, clamps, or packing material. Any instructions given on the tags attached to the instrument should be carefully followed and such tags removed.

To remove the rear cover, press down firmly at the top center of the cover. At the same time exert pressure away from the case. When the cover is sufficiently deflected, the latch will disengage from the case. Then lift off the cover.

Chart Module—At the front of the instrument, depress the chart module catch-release lever, Fig. A1. After depressing this lever, pull out the chart tear-off bar, which also serves as a handle for raising and lowering the chart module. The chart module will tilt about 30 degrees and lock in this position. It can be extended a full 90 degrees (no higher) by depressing the lever again and again raising the chart module. In this case while raising it, support it by hand rather than by the chart tear-off bar. While in the raised position, check to insure that the amplifiers, Fig. A3, are firmly seated in their plug-in connectors (or check simply by lowering the chart platen). Since the chart module does not lock in the 90-degree position, return it to the 30-degree position.

To return the chart module to its normal or near-vertical position, depress the lever while holding the tear-off bar, and gently ease the module back to its normal position until it locks there. In the normal position, the chart platen is actually tilted 7 degrees for convenience in reading the chart.

Recording and Input Modules—The recording and input modules are mounted as an integral assembly and as such slide in and out of the case together. To withdraw this assembly, depress the chassis catch-release lever, Fig. A1, and, using the chart tear-off bar as a handle, pull out the assembly until it locks in position. The support stand, Fig. A1, stabilizes the instrument when the recording and input modules are in the fully-extended position.

On fixed span instruments, the input module has a small printed-circuit card mounted in a connector beside the bottle holder tray. See Fig. C1. Make sure this card is firmly seated in position.

There are at least two additional printed-circuit cards in each input

module. These are secured in position with screws and should require no further attention at this time.

If the instrument is to be used with thermocouples, an auxiliary reference junction module is supplied with it. This module can either be battery operated or energized from the line supply. The battery-operated version plugs directly into the input module and has separate terminals for the thermocouple connections. The line-operated version, on the other hand, can be wall or bench mounted, and has separate input and output screw terminals. The input connects to the thermocouple and the output to the recorder through separate leads. In addition, the line cord plugs into 120 V 60 Hz.

For further information on these modules, refer to Section L, Thermocouple Reference Junction Modules.

MOUNTING

The Speedomax instrument is supplied for tabletop, rack, or panel mounting. Fig. A2 gives overall case dimensions.

The instrument case should be connected to a good earth ground unless specific exception is made on the instrument wiring diagram. The use of the grounding screw on the terminal board of the instrument will effect such grounding. Simply connect this grounding screw to an earth ground bus. For tabletop mounting make sure the ground lead (green conductor terminating in grounding prong of three-prong plug, Fig. A3), connects to earth ground.

TEMPERATURE LIMITS

The instrument should not be installed in locations where the ambient temperature exceeds the range 16°F and 122°F (-9°C to 50°C).

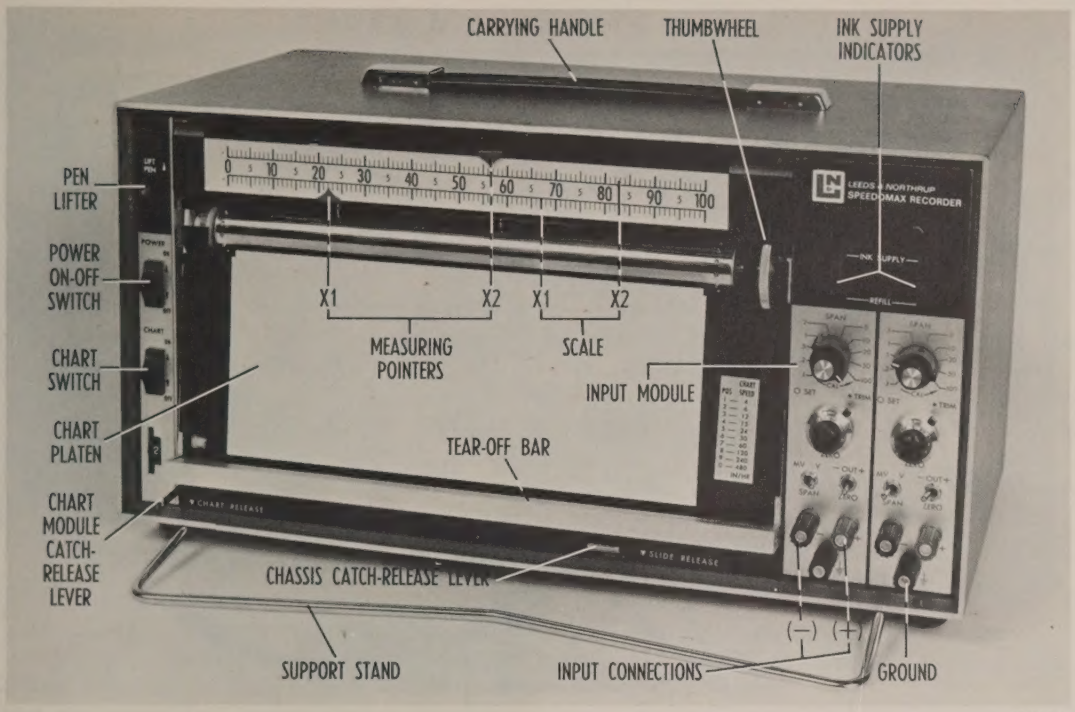
WIRING CONNECTIONS

Detailed wiring connections are shown on one or more diagrams supplied with the equipment.

All wiring diagrams are self-explanatory. In making connections, however, the user is advised to observe the procedures and precautions which follow.

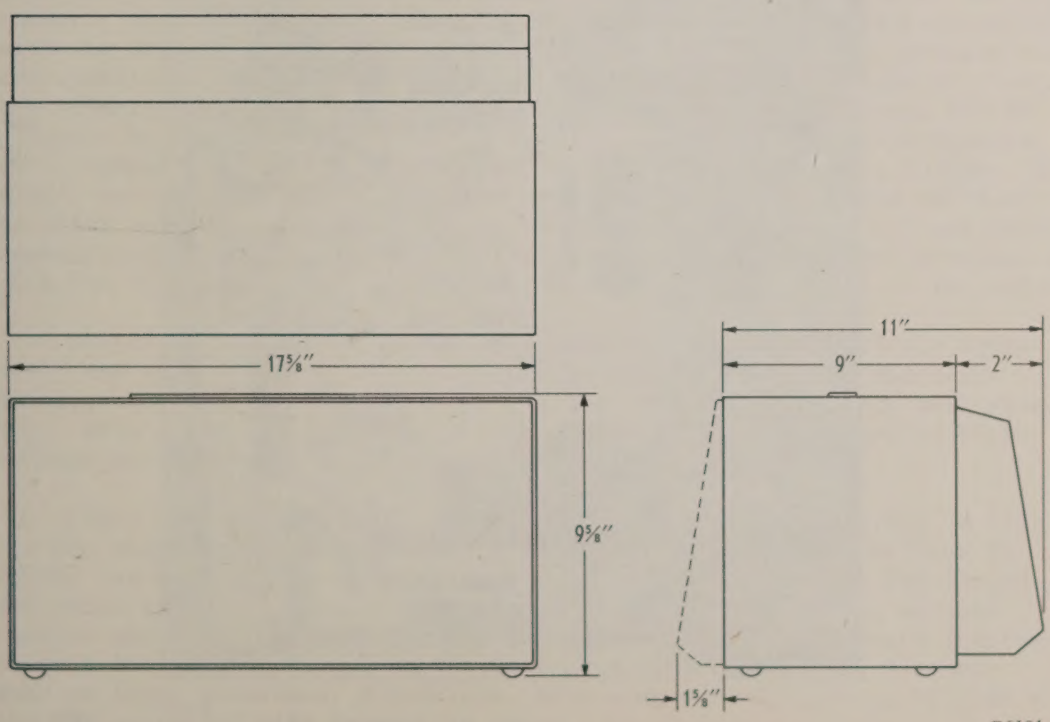
For tabletop instruments, a line cord is supplied for connection to an ac source. Input connections are made at the front of the input module, or at the rear input terminal board, Fig. A3.

Rack- or panel-mounted instruments are wired in similar fashion except that the ac line leads, and input leads for rear terminal board



E6190

Fig. A1–Speedomax XL, Model 602 (two-pen) Recorder. Input module has AZAR type spans on left side (X1), fixed span on right side (X2).



E6191

Fig. A2–Recorder case outline/mounting dimensions.

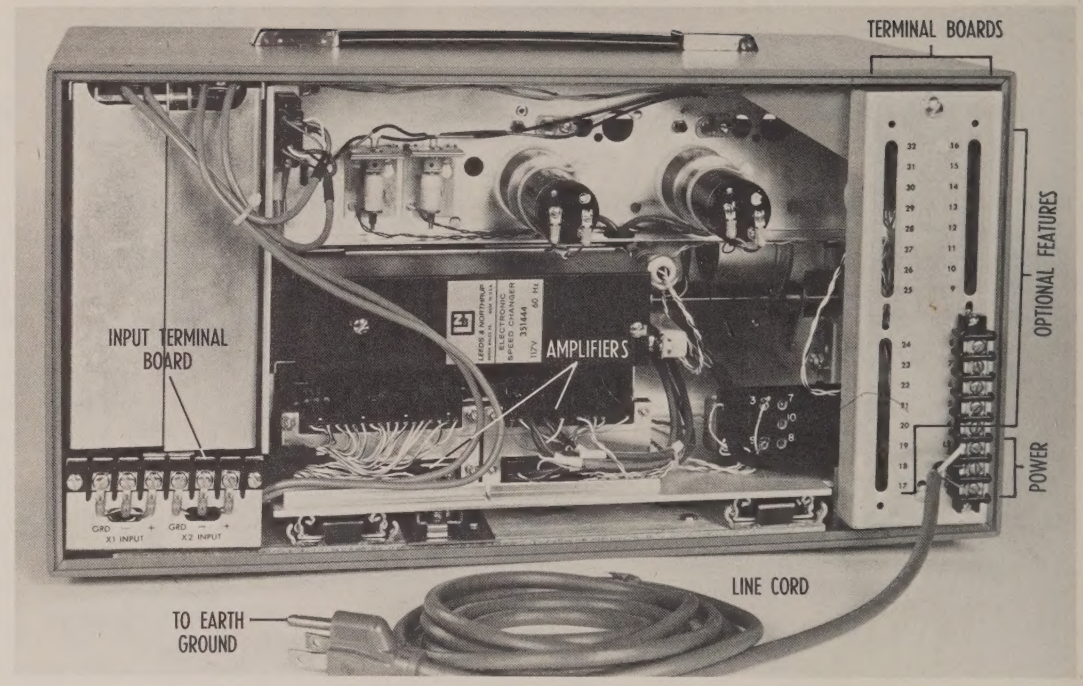


Fig. A3–Rear view of Speedomax XL, Model 602 Recorder, cover removed, showing amplifiers and wiring connections. Terminal boards only supplied where required.

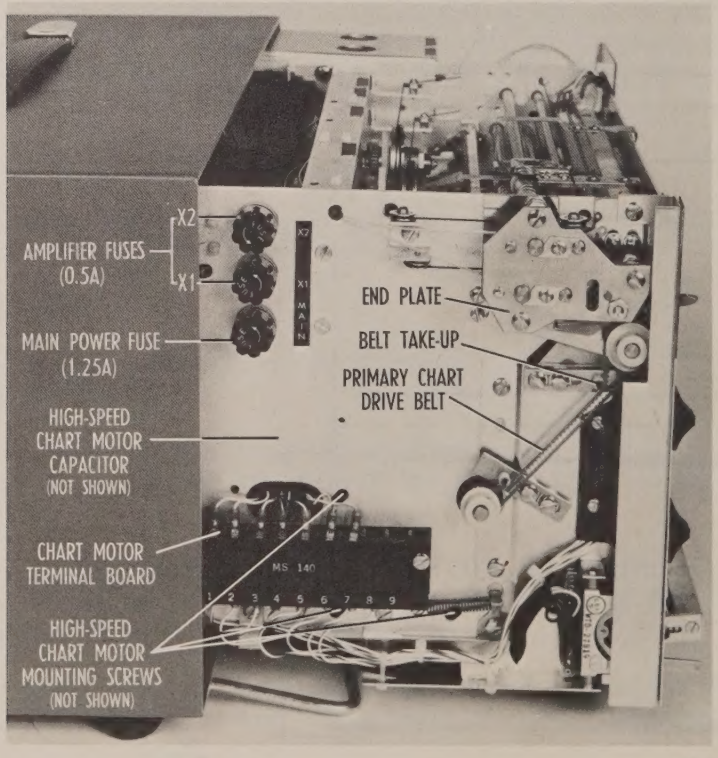


Fig. A4–Left side view of recording module.

connection, are brought in by means of conduit runs. Keep the primary element input(s) in one conduit run and ac power in a separate run. Primary element inputs are never to be included in the same lead-in or conduit run with power leads. This precaution must be taken to minimize pickup in the input leads. If desired, the back cover can be left in place and leads brought in through slots in the cover.

Connect line supply of the proper voltage and frequency as specified on the nameplate, which is located on the back of the chart platen and visible by lowering the chart platen. Power supply voltage must be within the limits of 107-127 V 60 Hz. When making the power connection on rack-mounted instruments, make sure the L2 terminal of the terminal board is connected to the grounded side of the power line. Use an isolating transformer if one is required, to permit grounding of the L2 terminal.

Power to all parts of the measuring instrument is supplied through two of three fuses and two switches, depending upon how the instrument is equipped. The switches are located at the left side of the instrument, Fig. A1. Fuses are located on the left side plate of the recording module. See Fig. A4. Table A1 provides switch and fuse data.

Connect the emf source to the recorder input terminals, front or rear (not both). Connect thermocouple inputs to the reference junction module. For the battery-operated reference junction module, plug this unit into the recorder input terminals. For the line-operated version, connect the line cord to 120 volts, 60 Hz; connect a separate pair of copper leads from the output terminals of the module to the input terminals of the recorder. Maintain polarity throughout. Observe any instructions supplied with the primary element voltage source. Although no special precautions are usually required, it may be necessary in some installations to shield the primary element leads or to route them so as to avoid strong fields produced by transformers, electric welding equipment, induction heaters, etc. Connect the shield, where applicable, to the negative (-) input terminal, unless the shield is already connected to ground at the emf source; in which case do not connect the shield to (-). Simply cut off and leave unconnected or floating. If connected at both ends the shield provides a path for circulating currents which could negate the purpose of the shield.

Where the instrument is used for measurement on high-voltage equipment, one side of the primary element should be grounded at the high-voltage equipment if the measuring circuit arrangement permits such grounding. This is to protect both personnel and instrument in case of high-voltage breakdown to the primary element.

Where such grounding of the primary element is not possible, a voltage may exist between the primary element and ground. This voltage is called the common-mode voltage (CMV). At no time should the CMV exceed 200 volts ac or dc. Where the CMV exceeds 30 volts ac or dc, extreme caution should be observed when making adjustments to components located beneath the various covers on the instrument. For measuring elements such as input terminals, slidewires, balancing motor(s), etc., will be at the CMV potential with respect to case.

The instrument case should be grounded unless specific exception is made on the wiring diagram. When grounded, the bottom input terminal, marked ⏚, is also ground. Use this ground terminal to ground other instruments or to reduce input interference in such circumstances wherein grounding would be of help.

For wiring connections to provide a reversed range, see Section N, Reversed Ranges.

TABLE A1–SWITCH AND FUSE DATA

SWITCHES	
ONE- AND TWO-PEN INSTRUMENTS	
ONE CHART SPEED	TWO CHART SPEEDS
2 SWITCHES: #1 SWITCH: 1) Amplifier on 2) Off #2 SWITCH: 1) Chart on 2) Off	2 SWITCHES: #1 SWITCH: 1) Amplifier on and chart switch energized 2) Off #2 SWITCH: 1) High speed (H1) (Chart) 2) Low speed (LO) 3) OFF

FUSES*					
ONE-PEN INSTRUMENT			TWO-PEN INSTRUMENTS		
Description	Location	Rating	Description	Location	Rating
1 POWER	Lower	1.25 Amp.	1 POWER	Lower	1.25 Amp.
1 Amplifier	Middle	0.5 Amp.	2 AMPLIFIER: X1	Middle	0.5 Amp.
			X2	Upper	0.5 Amp.

* Observed from left side of instrument. See Fig. A4.

Section B-PREPARATION FOR OPERATION

CHART INSTALLATION

The number of the Leeds & Northrup chart to be used is marked on the nameplate inside the instrument case.

To install the chart, follow the sequence of steps shown in Fig. B1.

FILLING INK BOTTLE

The ink bottles, Fig. B2, are supplied already installed in the instrument. Withdraw the chassis as described in Section A, Unpacking, Recording and Input Modules. Use red ink for the X1 pen (left bottle) and blue or black ink for the X2 pen.

Insert the extension tube of the supply bottle into the vent hole of the ink bottle cap until it bottoms in the bottle. Gently squeeze the supply bottle to fill the recorder ink bottle to the neck (no higher), as illustrated in Fig. B3. Fill slowly to avoid making air bubbles. Then remove the supply bottle and proceed to prime the pen as outlined below.

PRIMING PEN

Raise the pen lifter and place some absorbent material such as a paper towel, cloth, etc., beneath the penpoint which is to be primed. With the index finger closing the vent hole on the ink bottle, gently squeeze the bottle, as illustrated in Fig. B4A, to start ink through the capillary system. When the bottle has been squeezed sufficiently, remove the index finger from the vent hole and release pressure on the bottle. Then start again. Maintain this squeezing-releasing action until ink starts to flow out of the penpoint and no entrapped air bubbles are evident in the capillary.

When the ink starts to flow during the priming procedure, it should squirt out of the penpoint in a thin stream. If it comes out in drops, then a restriction is present in the system. Such a restriction could be located in the penpoint or it could be caused by crimping of the plastic capillary or extra-flexible tubes, Fig. E1. Remove the restriction by uncrimping the tubes and/or by cleaning the penpoint as directed in Section E, Care of Pen and Ink Supply, Failure of Pen.

As an alternative to priming the pen in the manner described above, the pen may also be primed using the syringe, as illustrated in Fig. B4B. With the pens lifted, simply connect the end of the rubber capillary over the penpoint. The use of tweezers will facilitate this step. Then slowly withdraw the plunger of the syringe until ink appears in the syringe. Withdraw a sufficient amount of ink to be sure that there are no air bubbles present in the system. Then disconnect the syringe from the penpoint without reversing the direction of plunger motion, and lower the penpoint onto the paper.

Upon completion of the priming operation, return the recording module to its original position inside the case. When doing this, check to be sure the capillary tubes do not get kinked or squeezed.

Priming need be repeated only when any part of the capillary system is emptied during cleaning, if it is allowed to run dry, or if any opening occurred in the capillary system that would permit air to enter and cause a stoppage of the ink flow.

SCALE, POINTER, AND PEN LINEUP

All instruments are completely adjusted and tested before leaving the factory and should be in perfect operating condition when received. It is advisable, however, to make the following simple checks at the time of installation.

With the instrument turned off, rotate the drive cord pulley, as illustrated in Fig. B5, to bring the X1 pen downscale (left end) until the penpoint is on the first calibrated line of the chart grid. Under this condition the X1 pointer should be on the first calibrated line of the scale. Then rotate the X1 drive cord pulley until the mechanical stop in the left direction is reached. The pointer should now be on the dot below the first calibrated line on the scale, and the pen should be on the first line of the chart below the calibrated grid.

Repeat the above procedure for the X2 function, where applicable.

If the instrument does not meet the foregoing requirements correct the lineup as instructed in Section H, Scale, Pointer, and Pen Lineup.

INSTRUMENT STARTUP

After completion of the preparations as instructed to this point, the instrument may be placed in operation. Slide the power on-off switch, Fig. A1, to the ON position. This position allows the amplifier to warm up and the instrument to be used for indication only. On single chart speed instruments, also slide the chart switch to the ON position. In the case of dual chart speeds, set the chart switch to the high (HI) or low (LO) position.

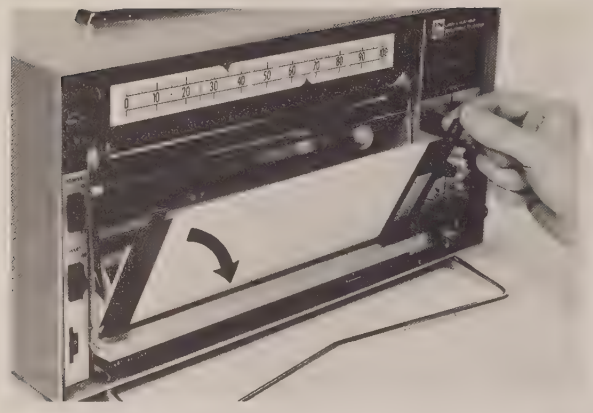
Note that when the power on-off switch is in the on-position, the ink-supply lamp also serves as an "ON" indicator light.

On instruments equipped for thermocouple measurements, in addition to energizing the instrument amplifiers and chart motors, also energize the thermocouple reference junction module. Snap the on-off switch to ON for self-powered units or plug in the line cord on line-operated units.

AMPLIFIER GAIN AND DAMPING

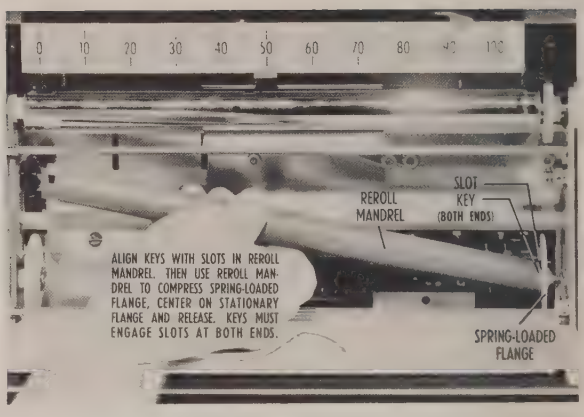
There is no amplifier gain adjustment in the instrument. Gain is taken care of automatically through resistors on the span card or through the switching arrangement of the SPAN SET dial.

A damping adjustment, however, is provided. It has been set at the factory and requires no further attention on the part of the user. If inadvertently disturbed or adjustment is found necessary at any time, refer to Section J, Factory Adjustments, R30 Check.



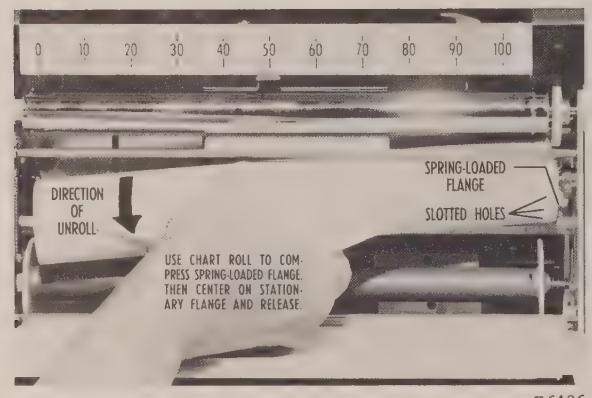
E6194

(a) Swing down chart platen.


REROLL MANDREL
SLOT KEY (BOTH ENDS)
ALIGN KEYS WITH SLOTS IN REROLL MANDREL. THEN USE REROLL MANDREL TO COMPRESS SPRING-LOADED FLANGE, CENTER ON STATIONARY FLANGE AND RELEASE. KEYS MUST ENGAGE SLOTS AT BOTH ENDS.
SPRING-LOADED FLANGE

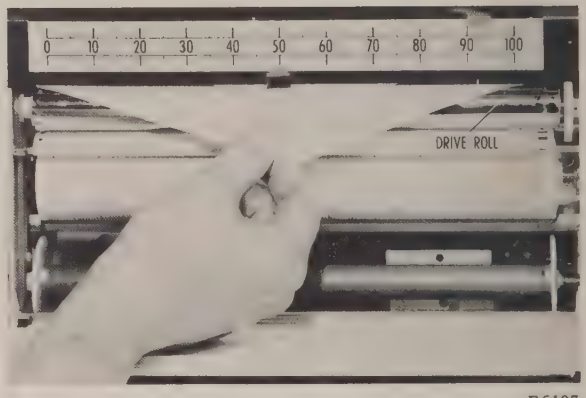
E6195

(b) Insert reroll mandrel.


DIRECTION OF UNROLL
SPRING-LOADED FLANGE
SLOTTED HOLES
USE CHART ROLL TO COMPRESS SPRING-LOADED FLANGE. THEN CENTER ON STATIONARY FLANGE AND RELEASE.

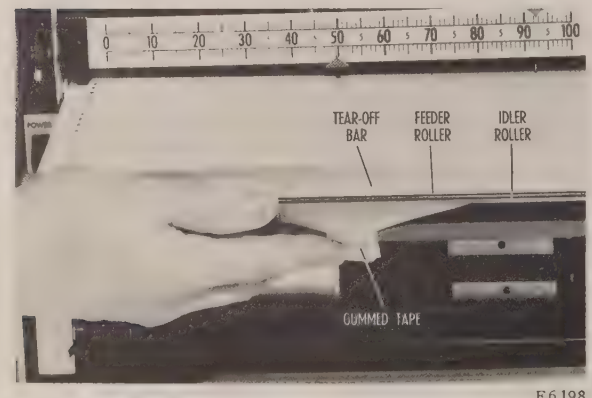
E6196

(c) Insert new chart roll.



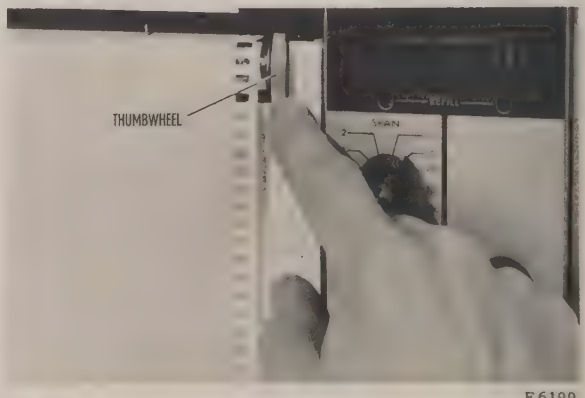
E6197

(d) Pass paper through guide and over drive roll. Then close chart platen.



E6198

(e) Pass paper down over chart platen, under tear-off bar, and between feeder and idler rollers. Then raise chart module to position shown. Attach gummed tape to end of chart paper and after aligning paper between flanges, press tape to reroll mandrel.



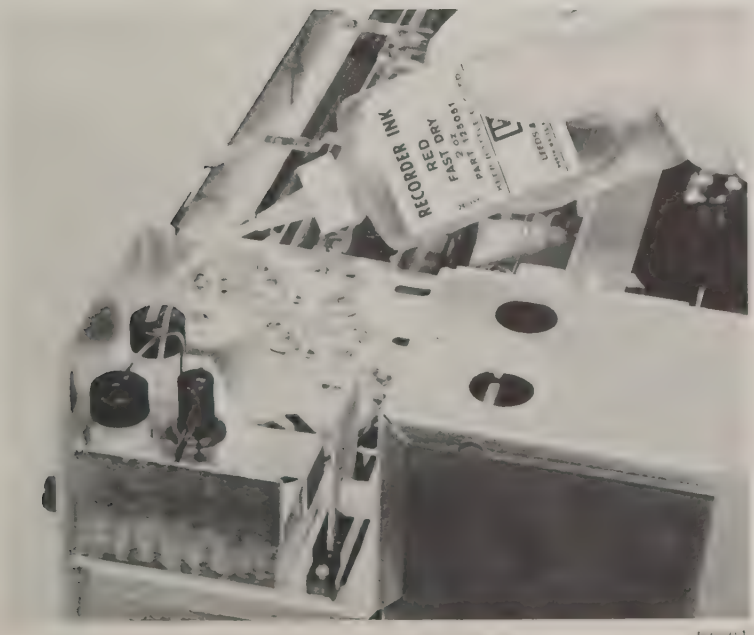
E6199

(f) Turn chart drive roll thumbwheel until chart paper is well started on reroll mandrel.

Fig. B1–Chart installation.

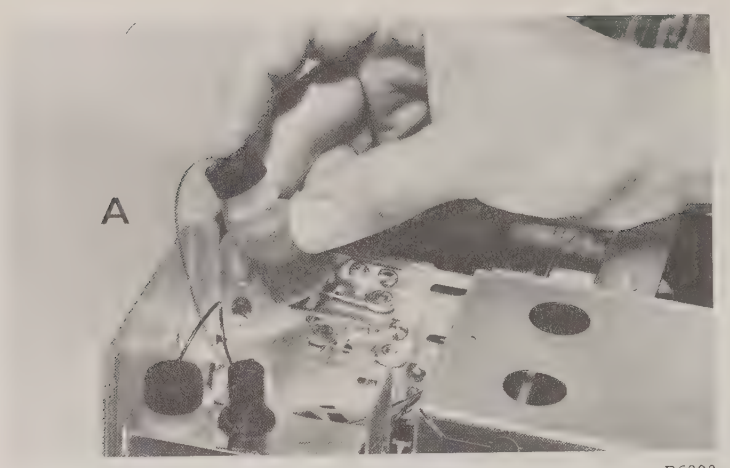
E6200

Fig. B2–Ink bottle installation.

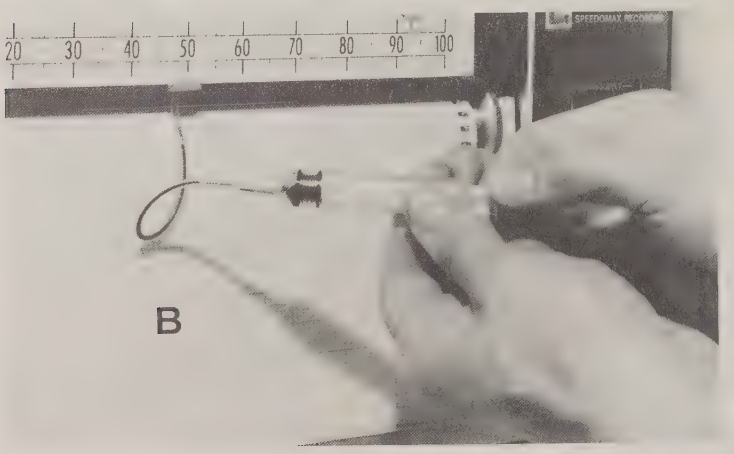


E6201

Fig. B3–Filling ink bottle.

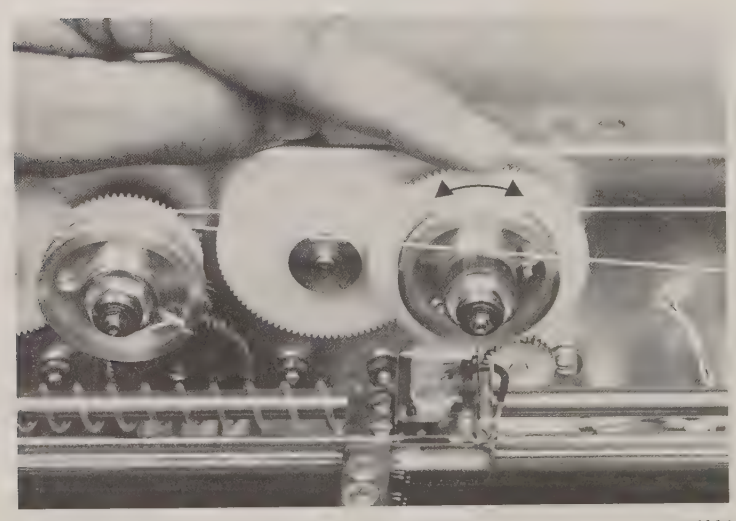


E6202



E6203

Fig. B4–Illustrating pen priming by using: A–ink bottle; B–syringe.



E6204

Fig. B5–Manual rotation of drive cord pulley to move pen carriage and/or slidewire contacts.

Section C-OPERATING ADJUSTMENTS

INPUT CONNECTIONS

As outlined in Section A, Wiring Connections, the only external connections necessary (other than the ac line voltage source) are the dc input leads. Connect these to the (+) and (-) input terminals at the front or rear as indicated in Section A. With maximum zero and span settings, the greatest emf that can be measured is 100 volts and the smallest is approximately 40 microvolts. Transient or sustained inputs exceeding the range established may cause serious damage to the instrument.

CONTROL FUNCTIONS

All controls are located on the input front panel, Fig. C1. These consist of the following for instruments so equipped.

SPAN SET Dial—A 10-position switch which sets the millivoltage span of the instrument according to the position of the dial indicator, i.e., .1, .2, .5, 1, 2, 5, 10, 20, 50, and 100 MV (millivolts) or V (volts), depending upon the setting of the SPAN MV-V switch position.

SPAN TRIM Knob—The center knob (potentiometer) in the SPAN SET dial that: in the maximum counterclockwise (detent) position is used to calibrate the instrument for the required span as outlined above; and when turned clockwise, reduces the span of the instrument by as much as 2-1/2 times the value set by the SPAN SET dial. For example, the 1 mV span can be reduced to 0.4 mV, 20 mV to 8 mV, 100 V to 40 V, etc., provided the SPAN MV-V switch is in the corresponding MV or V position. If a particular setting lends itself to a choice between SPAN SET positions, use the SPAN SET position which comes closest to the one desired. That is, for a span of 45 mV, for example, use the 50 mV position rather than the 100 mV position.

ZERO Knob—A 10-turn potentiometer which sets the zero of the span or the amount of negative or positive suppression on those ranges requiring this type of measurement. Provides an uncalibrated zero adjustment of ±100% of span when the ZERO OUT-IN switch is in the IN position. As an option, it can be supplied calibrated.

SPAN MV-V Switch—Selects the input to be measured, in millivolts (MV position) or volts (V position) as set on the SPAN SET dial.

ZERO OUT-IN Switch—In the IN position, allows the ZERO knob to be effective as described above for the ZERO knob. In the OUT position, the ZERO knob is ineffective and zero is fixed at the zero point of the scale.

For calibrated zero (optional) the ZERO switch is marked -OUT +. In the (-) position the zero point is moved below the zero point of the scale, and in the (+) position the zero point is moved above the zero point of the scale.

RANGE/SPAN ADJUSTMENTS

Determine the required span by algebraically subtracting the low-end value of the desired millivolt range from the high-end value. For example, a desired range of -9 to 21.7 mV requires a span of 30.7 mV; a desired range of 1.1 to 5.6 mV requires a span of 4.5 mV.

If the required span equals one of the twenty calibrated values of the SPAN SET dial and has zero (0) for the low-end value, follow procedure (1) below. If zero suppression or elevation are involved, follow procedure (2).

Thermocouple ranges, regardless of whether single span cards or AZAR's are used, have live zero adjust. Therefore, temperature ranges going below 0°C (32°F) can be set up with either arrangement (single span or AZAR).

1. Span Equals One of Calibrated Values of SPAN SET Dial.

(1) Set the ZERO OUT-IN switch to the IN position.

(2) Set the SPAN MV-V switch to MV for millivoltage measurements or to V for voltage measurements.

(3) Set the SPAN SET dial to the span which is just above the value to be measured; e.g., set on 5 for a measurement of 4, on 10 for a measurement of 9, etc.

(4) Connect the input to be measured to the input terminals.

If desired, the high end or 100 division can be moved downscale or suppressed, for example, to the midscale position. This provides in effect a range of 50 to 150. For ranges more complex than this, follow procedure (2) below.

2. Span Does Not Equal One of Calibrated Values of SPAN SET dial.

Assume that the required ranges are 1.1 to 5.6 mV (span = 4.5 mV) and -9 to 21.7 mV (span = 30.7 mV). To distinguish between the two, the latter is included in parentheses. The procedure for any other range is accomplished in a similar manner.

(1) Set the ZERO OUT-IN switch to the OUT position.

(2) Set the SPAN MV-V switch to MV.

(3) Set the SPAN SET dial at the 5 (50) position.

(4) Using a reference potentiometer, apply 4.5 (30.7) mV to the input. Adjust the SPAN TRIM knob until the pointer reads 100 on the scale.

(5) Set 1.1 (-9) mV on the reference potentiometer. Set the ZERO OUT-IN switch to IN and then adjust the ZERO knob until the pointer reads zero on the scale.

(6) Disconnect the reference potentiometer and connect the input to be measured to the input terminals.

Fig. C1—Input module. AZAR on left (X1), fixed span on right (X2).

Section D-CONTROL AND ALARM SWITCHES AND RETRANSMITTING SLIDEWIRE

CONTROL AND ALARM SWITCHES

The instrument may contain up to four switches per function. These switches are arranged to be operated by the rotation of an auxiliary drive shaft as illustrated in Fig. D1. The principal uses of these switches are:

Alarms—Switches can be connected to external circuitry to actuate alarms or other safety devices when certain preselected instrument readings are attained.

Simple Control—One or more switches can be used to turn a final control device on and off at predetermined readings and thereby control the variable being measured. This "on-off" or two-position method of control is described more fully in Section M.

Although the switches are mechanically part of the instrument, their wiring is entirely separate from that of the recorder balancing system. Therefore, the instrument can be placed in service, for measuring purposes, before any adjustments to the switches are made, and before switch wiring is installed.

SWITCH WIRING DIAGRAM

The internal wiring to the switch is not shown on the same diagram as are the measuring and motor circuits. Instead, a separate wiring diagram is furnished.

To identify the correct wiring diagram for a particular instrument, look at the instrument catalog number which is given on the nameplate located behind the chart platen. This is a coded number, and its third element represents the internal wiring arrangement. The circuit of this arrangement is shown in the particular wiring diagram which is marked with the same number.

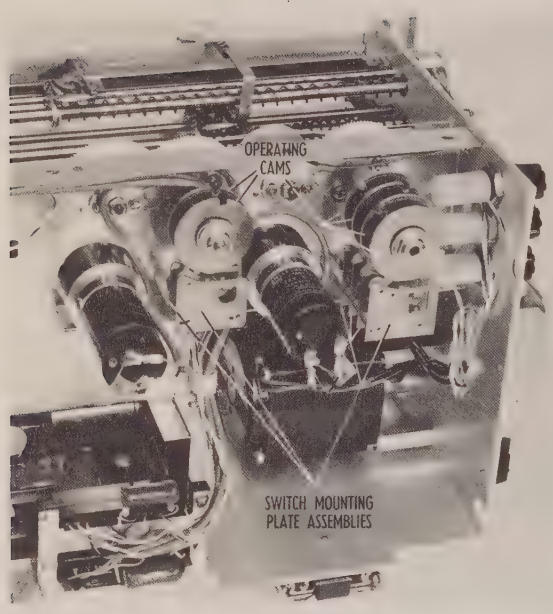
Example: If the instrument catalog number is: 601-61-082-3089-6-55-045, then the third element-082 - is the wiring number.

In connection with the switch wiring diagrams, note the following:

(1) When more than one switch is present, the switches are numbered on the diagram. Numbering is in order of switch position, starting with No. 1 for the switch nearest the gear drive.

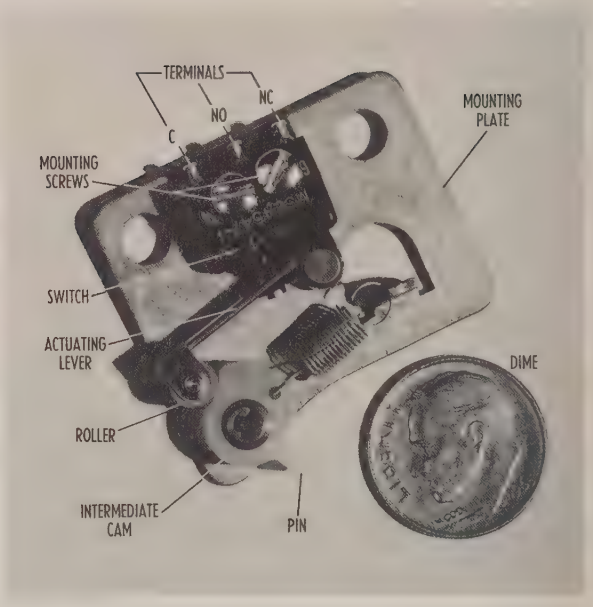
(2) The terminals of switches are designated H, L, and C,, standing for high, low and common, respectively. Definitions of high and low contacts are as follows:

A high contact is one which is closed when the measuring pointer



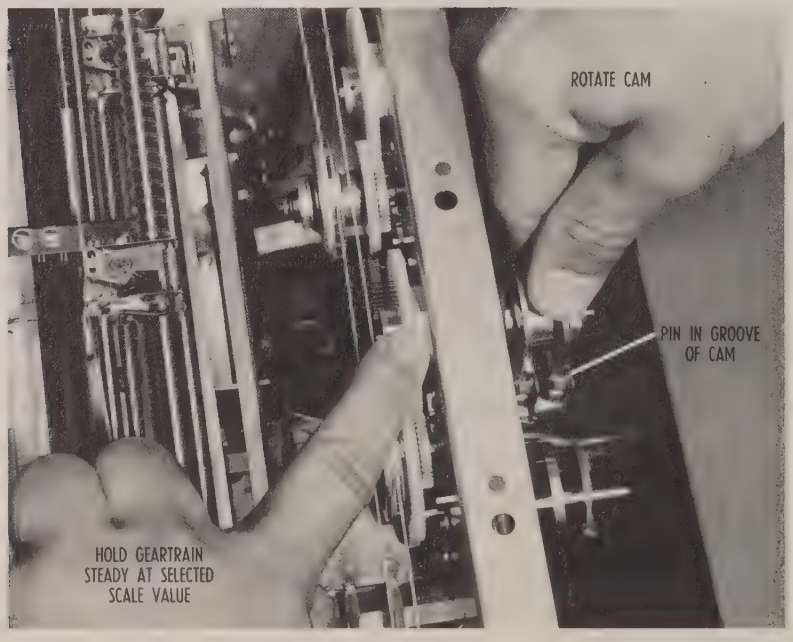
E6206

Fig. D1–Recording module, showing optional alarm and/or limit switches.



E6207

Fig. D2–Switch mounting plate assembly.



E6208

Fig. D3–Illustrating method of setting operating cams.

is between the set point of that contact and the right end of the scale.

A low contact is one which is closed when the measuring pointer is between the set point of that contact and the left end of the scale.

SWITCH CHARACTERISTICS

Fig. D2 shows the standard type of switch used in the instrument. This is an spdt snap-action switch which is actuated by an operating cam. The switch has no stable open position—for any position of its cam, either the high or the low contact will be closed.

The rated current interrupting capacity of a switch is as follows:

AC loads (noninductive)	1.0 ampere at 120 v ac 0.5 ampere at 240 V ac

Inductive loads—No rating can be given since capacity depends upon characteristics of the load and associated circuits.

PRELIMINARY SWITCH ADJUSTMENTS

When adjusting switches, connect an ohmmeter to the appropriate switch terminals, accessible at the rear terminal board (see Fig. A3), to determine when switching action occurs. Turn off all power to the instrument before making adjustments. The instructions given here apply to each switch.

To adjust, first rotate the drive cord pulley to a main division near the center of the scale. While holding the gear drive from turning with one hand, grasp the operating cam between thumb and forefinger of the other hand and turn in such a direction that the pin on the intermediate cam drops in the slot of the operating cam, as illustrated in Fig. D3.

SWITCH WIRING ARRANGEMENTS

Since many different types of switch arrangements are available—too many to be covered in a single manual—the switch wiring arrangement for an instrument is provided on a diagram supplied with that instrument. Wiring connections to the user's equipment should be made in accordance with that diagram. Each diagram shows only the external connections to the instrument terminal board, and specifies the various internal arrangements with which the external circuitry is suitable. It may be that for some combinations, not all of the switches in the instrument are used. If desired, such switches can be employed to operate alarms, signals, etc.

For a discussion of two types of control—two-position single point and two-position differential gap, refer to Section M.

RETRANSMITTING SLIDEWIRE CONSIDERATIONS

The retransmitting slidewire is of the conductive plastic type and has a resistance of 1200 ohms ±10%, with 0.1% linearity. (It is the same as the measuring slidewire.) For any other required resistance, a shunt resistor of the proper value must be applied by the user across the slidewire terminals in the recorder. The value of the shunt is determined by the following formula:

$$S = \frac{1200\ K}{1200 + K} \qquad \text{where}$$

K = value of shunt to be determined for a particular external value S.

For example, suppose the final shunted value S is to be 400 ohms:

$$400 = \frac{1200\ K}{1200 + K}$$

$$400\ (1200 + K) = 1200\ K$$

$$480000 + 400\ K = 1200\ K$$

$$K = 600 \text{ ohms}$$

The power that the retransmitting slidewire can safely handle is 3 watts, which indicates a maximum voltage of 60 V dc.

Unless the retransmitting slidewire is used in conjunction with equipment supplied by L&N Company, wherein all interconnections between retransmitting slidewire and auxiliary equipment are accounted for or supplied by L&N Company, the user must provide all such related circuitry, based upon the above considerations.

Section E-ROUTINE MAINTENANCE

This section covers the few routine maintenance procedures required during normal operation of the instrument.

CARE OF PEN AND INK SUPPLY

Refilling—It is recommended that the ink bottle be refilled when the ink level falls to the point indicated on the front of the instrument. The see-through slot provides convenient checking from outside the instrument. See Fig. A1. The ink supply should not be allowed to run below the indicated limit since this necessitates repriming after refilling. If it is allowed to run completely dry, this may also permit ink to dry inside the capillary system with consequent clogging of the system.

To refill, see Section B, Filling Ink Bottle. Also reprime the pen if necessary as instructed under Priming Pen in that same section.

Failure of Pen—If the pen stops inking while the bottle contains sufficient ink, it may be possible to start the ink flow by one of the following methods:

—Moisten a finger and draw it across the penpoint.

—Repeat the priming procedure.

To insure that no foreign particles remain in the capillary system, continue forcing ink through the pen. When the system is clean, the ink will squirt out of the pen in a fine stream.

If neither of the preceding methods achieves the desired result, reverse prime the system to draw all of the ink back into the ink bottle. This is done by first squeezing the ink bottle. Next, close the vent hole, and then slowly release pressure on the bottle. It may be necessary to repeat this reverse priming procedure several times to draw the ink out of the capillary system. For a totally clogged pen, open the capillary system near the pen, as explained in the following paragraph.

As an alternative to removing the ink in the manner described above, use the syringe, after first removing the ink bottle from the bottle cap and opening the capillary system by pulling out the reservoir connector from the plug. See Section B, Priming Pen, for the proper procedure of using the syringe. Then remove the pen assembly from the pen carriage. To remove a pen assembly, see below, Pen Replacement.

Insert a clean, unburred pen cleaner into the nib end of the pen. Push the cleaner no farther than 1/8" into the pen nib to dislodge and clean out any particles clogging the pen. Flush the pen assembly using a plastic squeeze bottle and water. Place a tube over the pen nib and force water backwards through the nib and metal tube until water flows freely

out of the system. After cleaning, dry thoroughly. Before replacement, note that the reservoir connector (installed in the groove provided) points directly away from the pen lifter setscrew, or at about a 60-degree angle with respect to the pen carriage shafts, and the reservoir plug is firmly seated. Prime the pen after reconnecting the reservoir connector with attached extra-flexible tube and replacing the pen assembly in the pen carriage.

If the pen cleaner cannot be pushed into the pen nib, install a new pen. Place the clogged pen (with plastic reservoir plug) in alcohol or hot water for a short time. Then, dislodge and clean out the particles clogging the pen with a clean, unburred pen cleaner as directed in the preceding paragraph. Remove any fluid from the pen and allow the pen to dry thoroughly before using it again. Drying of the pen can be facilitated by air purging.

> Caution: To prevent damage to the sapphire pen nib, make sure that the wire pen cleaner is always removed in a straight line with respect to the hole in the pen nib.

Pen Replacement—Refer to Fig. E1 unless otherwise indicated. Important: In following these instructions, take care not to bend or otherwise damage the penpoints.

Turn off power to the instrument and set the recording module in the fully out position. Remove the ink from the capillary system by reversing the priming procedure outlined above under Failure of Pen. Set the pen carriage at a scale limit, away from the chart guide. Then withdraw the reservoir connector from the plug in the auxiliary reservoir.

Using a fingernail, pencil point, etc., spring out the flexible mounting support to release the pivots from the mounting supports. When doing this, take care not to bend the flexible mounting support more than necessary. Then lift the pen from the instrument.

For removal of the X2 pen, first move the X1 pen downscale against the left end and the X2 pen slightly upscale from the X1 pen (but below the chart paper guide), using the drive cord pulley, Fig. B5. Next, loosen the retaining screw on the clip that holds the rear X1 pen carriage shaft in place. See Fig. E2. Move the clip slightly to permit clearance for the shaft, and then slide the shaft to the left until it clears the X2 pen carriage. Proceed to remove the X2 pen in the same manner as described above for the X1 pen.

Should both pens be removed at the same time, each can be identified by its design: For example, the X1 pen has the larger radius of pen curvature and fits the pen carriage with the red pointer; the X2 pen has the smaller curvature and fits the carriage with the blue pointer.

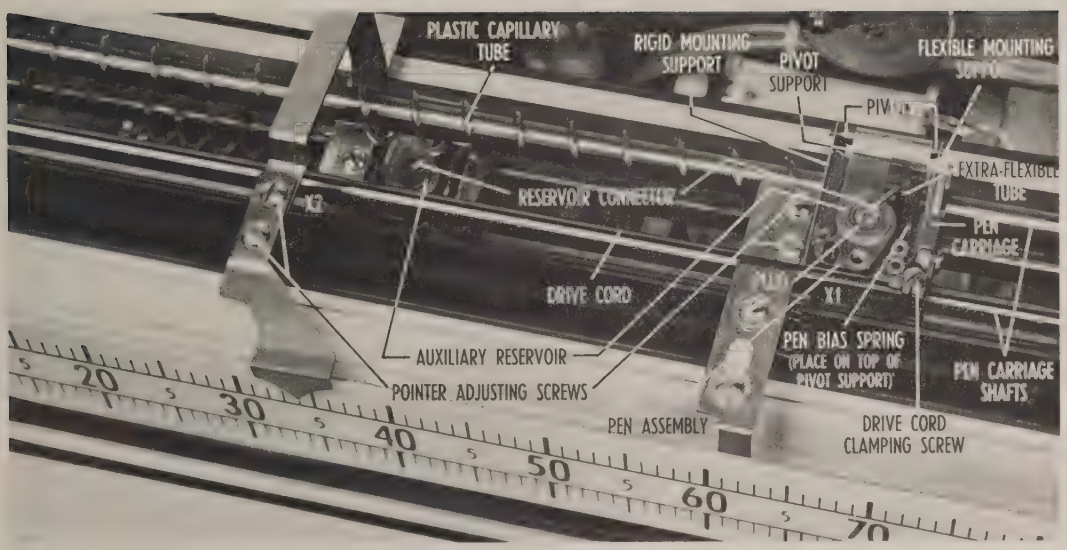
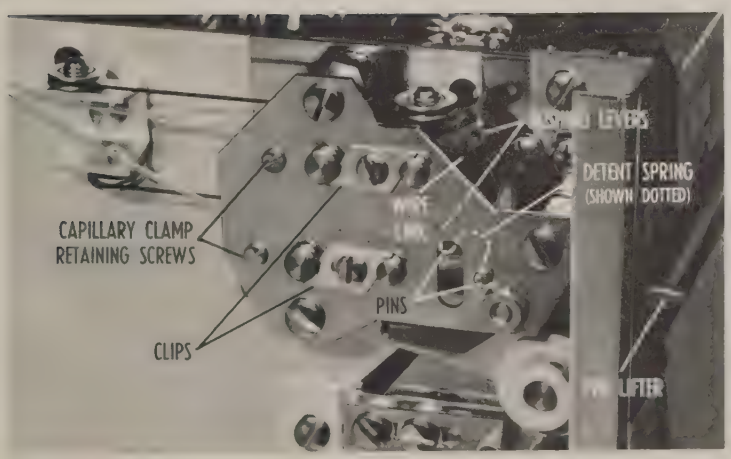


Fig. E1–Installation of X1 and X2 pen assemblies. E6209



E6210

Fig. E2–Closeup of components at left end of pen carriage shafts.

To replace the X1 pen assembly, reverse the above procedure. Use tweezers to facilitate handling, and wrap the extra-flexible tube around the pen carriage spacer. Then insert the reservoir connector in the cap of the auxiliary reservoir. Push into place until firmly seated in the groove provided. Then secure in position between the mounting supports, making sure that the pen bias spring is on top of the pen pivot support as shown in Fig. E1. Take the same care in springing out the flexible mounting support that was exercised in removing the pen. When properly mounted, the pen assembly will swing freely on the pivots without shake of the penpoint, and the penpoint will be biased against the chart paper when the pen lifter is down.

In a similar manner, replace the X2 pen assembly. Following replacement, reposition the rear X1 pen carriage shaft and lock in place with the retaining screw and clip. Check to be sure that the clip fits in the undercut of both X1 pen carriage shafts before tightening securely.

Upon replacement of a pen assembly, make the following checks:

(1) That orientation of the reservoir connector is as shown in Fig. E1.

(2) That the extra-flexible tube is not twisted, i.e., that it takes its natural shape as much as possible around the pen carriage spacer.

(3) That the pens—with pen lifter in the down position—pass each other without touching. Rotate a drive cord pulley (Fig. B5) to make the check. Check both at a downscale and upscale location.

(4) That the pen lifter, when actuated to the up position, raises both pens off the paper about 1/16". And when actuated to the down position, allows both pens to touch the chart paper.

If adjustment is required, refer to Section G, Pen Adjustments.

Replacement of Plastic Capillary—It is recommended that the plastic capillary tube (Fig. E1) be replaced every three years. However, should extreme operating conditions cause the tube to lose its elasticity, replace the tube whenever this occurs. Check the elasticity of the tube every three to six months. It is also recommended that the extra-flexible tube and reservoir plug, Fig. E1, be replaced whenever the plastic capillary tube is replaced.

To replace the plastic capillary and extra-flexible tubes, proceed as outlined below. The procedure applies for a two-pen instrument, with both systems being replaced. For a one-pen instrument, simply disregard reference to the second pen system.

(1) With power to the instrument turned off, slide out the recording and input modules. Then draw the ink from the capillary systems back into

the ink bottles by reverse priming the systems as outlined above, Failure of Pen. Next, remove the chart paper, scale, and pointer and slidewire contact assemblies.

(2) With the pen carriage away from the chart guide remove both pen assemblies. See above, Pen Replacement. Then loosen the drive cord clamping screw and remove the cord from under the pen carriage clamps.

(3) Remove the screws which hold the capillary clamp to the end plate on the left side, Fig. E2. Be careful not to lose the nutplate upon withdrawal of the screw. See also Fig. F1. One way to do this is to apply a piece of gummed tape to the nutplate. Upon removal of the screw, the nutplate can be lifted from the tape.

(4) Loosen the retaining screw on the clip that holds the rear X1 pen carriage shaft in place, if not already loose. Slide this shaft to the left. Also the rear X2 pen carriage shaft in a similar manner. Loosen the setscrew in the bushing lever that holds the front pen carriage shaft in place. See Fig. E2.

(5) Holding the pen carriages in one hand, slide the front pen carriage shafts out the left side just far enough to release the carriages from the shafts. When doing this, the pen lifter cam and spacer bushing are free to fall out from between the mounting supports of the pen carriage. Observe that the cam is on the left side, raised portion near the center, the spacer on the right. Disconnect the pen capillary from the rubber connecting tubing behind the chassis cross-support, take off the capillary clamp, and pull the capillary tube, with attached extra-flexible tube, from the instrument.

(6) Remove the capillary clamp from the pen carriage, taking care not to lose the screw and nutplate. Then remove the clamp and extra-flexible tube from the capillary tube and discard the capillary tube. See Fig. E3.

(7) Insert the end of the extra-flexible tube over the short uncoiled end of the new plastic capillary tube. Fasten the short uncoiled end of the plastic capillary tube to one of the capillary clamps in the following manner:

(a) Insert the first coil of the tube into the notch of the clamp as shown in Fig. E4.

(b) Fit the coil in the groove in the clamp so that the straight portion of the tube is in the position shown in Fig. E5. Press the straight portion of the tube into the straight groove of the clamp to complete this procedure.

Caution: Take care not to crimp the tube as this may damage it.

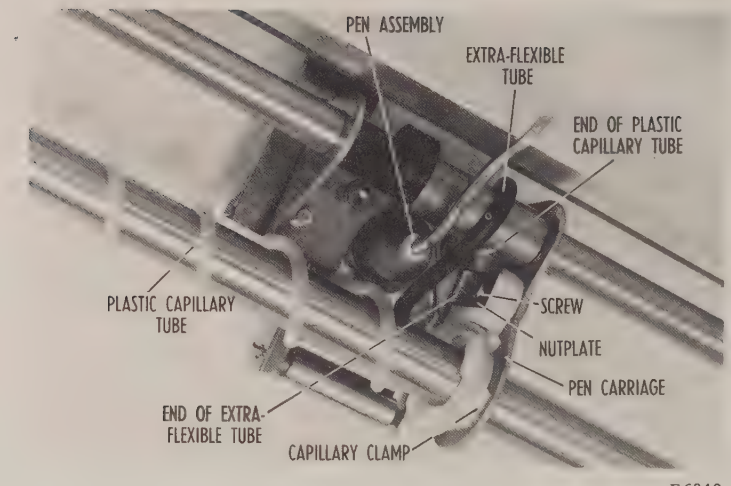


Fig. E3–Connection of plastic capillary tube to extra flexible tube on pen carriage.

Fig. E4–Insertion of first turn of plastic capillary tube into notch of capillary clamp.

Fig. E5–Positioning of straight portion of plastic capillary tube in straight groove of capillary clamp.

(8) Fasten the capillary clamp to the pen carriage. Use a nutplate and screw to secure the tube in the clamp and the clamp to the pen carriage. Make sure that the tubes are mounted as shown in Fig. E3 before tightening in position.

(9) Replace the other components by reversing the order of disassembly. To get the correct setting of the bushing lever, step 5, tighten the clip in place first. Then set the bushing lever against the end plate and tighten the retaining setscrew. Adjust for free movement of the bushing levers.

If a reservoir plug and extra-flexible tube are replaced, moisten the plug with a dampened cloth, paper towel, or paper tissue. Then orienting the groove so that the installed reservoir connector points toward the right rear of the recorder at about a 60-degree angle with respect to the pen carriage shafts, insert the plug into the reservoir. Be certain the plastic reservoir plug is inserted evenly so that it does not get crimped, and is fully seated to assure a good seal. Moisten the long end of the reservoir connector and then connect it to the other end of the extra-flexible tube. Wrap the extra-flexible tube around the pen carriage spacer and then force fit the other (short) end of the reservoir connector into the top of the reservoir plug.

(10) Prime the system as outlined in Section B, Priming Pen. Then check penpoint wipe, making any necessary adjustments as required.

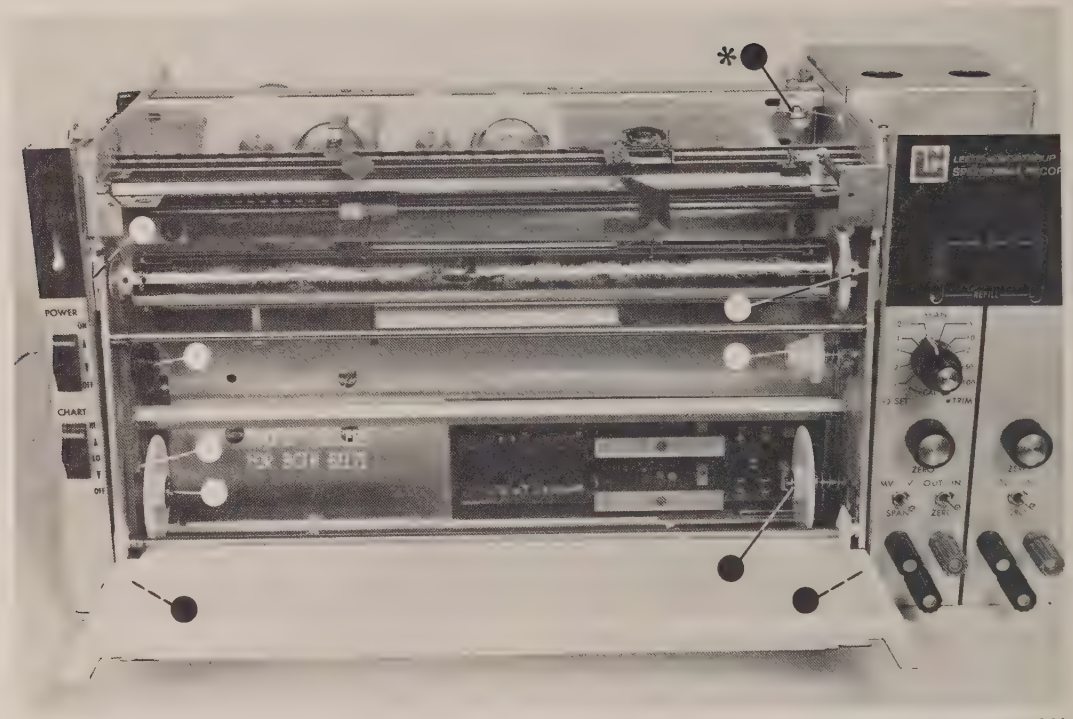
Also check scale, pointer, and pen lineup as instructed in Section H, Scale, Pointer, and Pen Lineup, and then check calibration as outlined in that same section.

CLEANING AND LUBRICATING

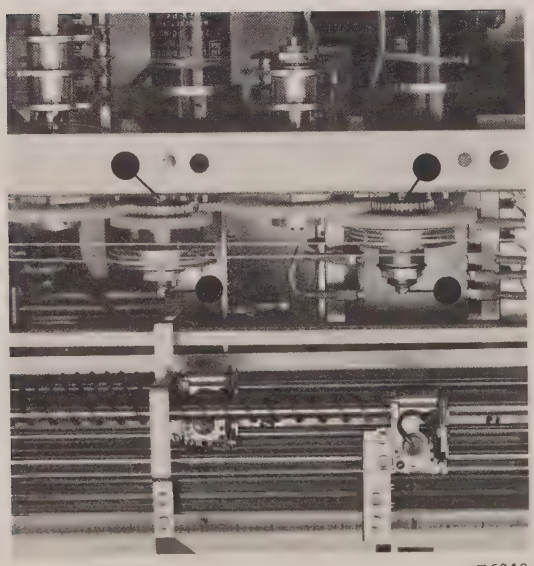
Since the Speedomax instrument is a continuously operating mechanism, occasional cleaning and lubricating are required. The schedule given below should be followed under normal conditions of use. Where the instrument location is very dusty, more frequent cleaning and lubricating may be necessary. Turn off power to the instrument. Then slide out the recording and input modules.

Cleaning—The measuring slidewire and the pen carriage shafts should be cleaned every two months and the chart reroll clutch assembly every six months, as outlined below. The ink bottle(s) should be cleaned only when necessary.

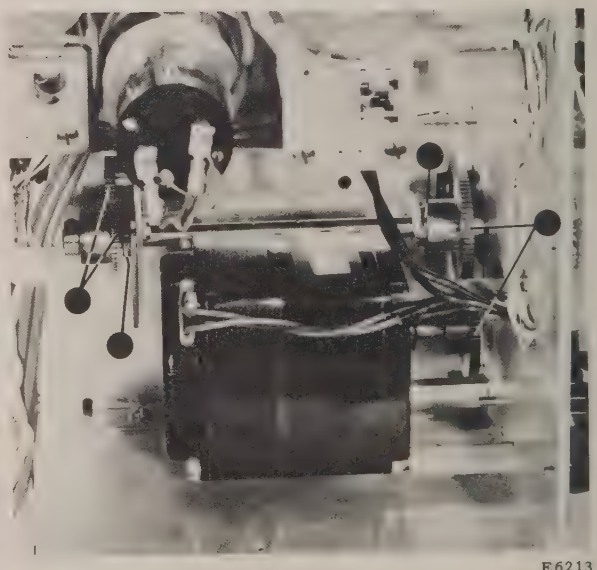
Measuring Slidewire—The measuring slidewire is of the conductive plastic type and usually requires only gentle wiping with a clean, dry cloth or tissue. However, should the slidewire become electrically noisy, wipe with a 1% solution of a detergent—such as Liquid Joy—and then with a clean cloth or tissue dampened with water. Do not apply any lubricant to the slidewire.



E6211



E6212



E6213

● LUBRICATE EVERY 6 MONTHS

* ALL BALL BEARING PULLEYS

Fig. E6–Lubrication schedule.

To avoid the possibility of disturbing the small sliding contacts, move the pen carriages to a scale limit while cleaning on the opposite side.

Pen Carriage Shafts—Move the pen carriages downscale against their low- or left-end stops to gain access to the pen carriage shafts, Fig. E1. Then place a small quantity of oil on a cloth and rub the shafts with it until they are clean. Leave a thin film of oil on the shafts for lubrication.

Chart Reroll Clutch Assembly—The chart reroll clutch assembly, Fig. F5, should be removed and cleaned every six months. Turn off the power to the instrument. Then remove the chart reroll mandrel. Next, remove the screw from the center of the clutch assembly; this screw has a left-hand thread. Loosen the belt by loosening the take-up roller, and then slide the clutch assembly off the shaft. Using the Standard Pliers No. 2, remove the retaining ring from the end of the assembly. Then lift off the thin steel washer, the large plastic reroll flange, the friction disk and the friction washer. Thoroughly clean the parts and then reassemble them. In reassembly, see that the fingers of the friction washer face the friction disk and that the notch in the friction disk lines up with the small hole in the flange of the bushing on which the parts are assembled. Keep the friction disk in this position while replacing the plastic reroll flange, steel washer, and retaining ring. Then replace the assembly and screw, and readjust the drive belt tension by moving the take-up roller in or out as required. The belt should have slack but not enough to jump the teeth of the drive gear.

Ink Bottle(s)—After an extended period of use it may be found necessary to remove and clean the recorder ink bottle(s). To do this, slide out the recorder and input modules and remove the ink bottle. Withdraw the ink from the capillary system by reversing the priming procedure as outlined above under Care of Pen and Ink Supply, Failure of Pen. Then unscrew the bottle from the cap. Wash out the bottle thoroughly and when dry, replace it. Now fill the bottle and prime the pen as outlined in Section B, Priming Pen.

Lubrication—Use a good grade of medium weight, non-detergent oil, e.g., L&N recorder oil (L&N Part No. Std. 763), to lubricate the points indicated in Fig. E6. Apply only one or two drops of oil at a time and wipe off any excess. On the drive cord ball bearing pulleys, be particularly careful that no oil gets on the drive cords, as this may accelerate wear of the cords. Other bearings, such as those located on the shaft that turns the switch operating cams, are permanently lubricated and therefore require no further lubrication.

To assure quiet operation from the chassis catch-release lever, lightly lubricate the metal surface on which the top of this lever slides.

A more suitable method of lubricating exposed parts, such as gear teeth, cams, etc., is to use a #3 or #4 artist's brush. Dip the brush in

oil, remove the excess by wiping across the lip of the container once, and then apply the oil-filled brush to the exposed part(s).

ADJUSTMENTS

Under normal conditions of use there are no electrical adjustments to be made on the instrument, including gain and damping, other than those for standard operation as outlined in Section C. However, should any potentiometers get inadvertently misaligned from their factory settings, refer to Section J, Factory Adjustments.

RECORDER INKS

Recorder inks supplied are of the fast drying type. This is a water base ink that dries quickly. Table E1 provides a list of available colors in various bottle sizes.

Because no ink can compensate for improper pen alignment or inadequate priming, make sure that:

(1) No air gets into the pen system through loose connections or poor priming techniques. Proper priming (purging of air) is especially important in capillary pen systems. Many failures that are attributed to pen clogging are actually caused by air bubbles. Force enough ink through the system to assure that all the air has been forced out.

TABLE 1-L&N FAST-DRYING RECORDER INKS

Bottle Size	Red	Black	Blue	Green
2 oz	125051	125131	125113	125114
8 oz	125060	125150	125151	125145
16 oz	125045	125104	125124	125146

(2) Pen pressure should be as light as possible, consistent with good writing qualities.

(3) The flat of the penpoint should be flat against the chart roll, i.e., 90° to the surface of the chart roll.

PART II SERVICING AND TROUBLESHOOTING

Section F-REMOVAL AND INSTALLATION OF PARTS

In servicing the instrument, it may be necessary to remove one or more parts. This section describes and illustrates such partial disassembly operations and also indicates, where necessary, the replacement or installation of the parts. In all cases where several steps are required to effect a removal or replacement, these steps should be followed in the order given. All power should be turned off until completion of the required operations unless otherwise noted. Most servicing can be completed via the rear, and/or by pulling out the recording and input modules to the extended position, as outlined in Section A, Unpacking, Recording and Input Modules.

TOOLS

An Allen wrench (for #2-56 screws—.035" across flats) and a syringe are supplied with the instrument. With the exceptions mentioned below, other tools that will facilitate work on the instrument include: a) small set of screwdrivers; b) offset ratchet screwdriver; c) tweezers; d) short piece of wire with hook on one end; e) long, thin-bladed screwdriver; f) small set of wrenches—3/16" to 1/2"; g) set of wire or plastic nut holders.

A number of Waldes Truarc retaining rings are used in assembling the parts. To facilitate removal or installation of these devices, the following tools, designed specifically for the purpose, should be available:

Alternate Field Pliers No. 0 -- for small external retaining rings (No. 12 to No. 23).
Standard Pliers No. 2 -- for all other external retaining rings in the instrument.
Grip Ring Pliers
Truarc Applicators -- for 1/4" and 3/16" E-Rings.

If not otherwise available, these pliers may be ordered from Waldes Kohinoor, Inc., Long Island City, New York 10001.

SLIDEWIRE CONTACTS

To remove, simply take out the two screws which secure the contact assembly to the pointer bracket and remove the assembly from the instrument. See Fig. F1. Note that the insulating bushings and strip underneath prevent grounding of the contacts and must therefore be replaced in the same manner. To replace, reverse the above procedure. Before tightening in position, align the contacts so that they track in the center of the conducting plastic slidewire paths (smooth black stripes). If contact adjustment is required, see Section G, Contact Force Adjustment.

MEASURING AND/OR RETRANSMITTING SLIDEWIRES

Using the drive cord pulley gear, Fig. B5, move the pen to the low or left end of the scale. Then take off the scale. Remove the screws which hold the pointer and slidewire contact assembly in position, Fig. F1, and take off these assemblies. Next, using a narrow-bladed screwdriver, pry off the snap-on connectors from the pin terminals at the right side. When removing connectors, apply pressure to the upper surface of the slidewire near the terminals, to avoid overstressing the adhesive which holds the slidewire to its mounting base. Observe that the connector wires are color coded—from front to rear, or top to bottom for X2—white, black, and red, with shield connected to the slidewire base. Then remove the mounting screw at the right and left sides. Be careful not to lose the insulating washers which are free to fall out. See Fig. F1. Note that the assembly is mounted on a set of brackets which are attached to the side plates; these brackets are factory set and should not be readjusted.

To replace, reverse the above procedure.

In the event the mounting brackets have been disturbed, leave all slidewire mounting screws loose. Also, do not replace the pointers and/or contacts until the assembly has been properly adjusted as indicated in Section G, Measuring Slidewire Assembly.

DRIVE CORDS

The pen drive cord is supplied precut to the proper length and has a bead on each end. The beads provide an anchor for the cord as well as facilitate installation of the cord.

Remove all pieces of the old cord and loosen the take-up pulley so that the pulley is free to just slide. Then install the new cord according to the general sequence of steps given in Fig. F2.

To get at the rear slot in the X1 drive cord pulley of a two-pen recorder, back out the clutch assembly nut to the end of the bushing. Loosen the setscrew that holds the drive cord pulley to the bushing, and then pull the drive cord pulley away from the delrin gear far enough to insert the bead in the slot. The use of a thin-bladed screwdriver will facilitate this step. Now push the drive cord pulley back into position and retighten the nut. See Section G, Drive Cord Clutch Adjustment. Then retighten the setscrew in the groove of the bushing.

When installing the drive cord around the ball bearing pulleys, particularly on the left side, the use of a small wire hook (straightened paper clip with a hook on one end) will facilitate this procedure.

After the cord is installed, check to see that it does not ride up on adjacent turns or on flanges of the pulley. Check by turning the drive cord pulley first in one direction and then in the other and observing the action of the drive cord.

Then clamp the pen carriage loosely to it. Align the pen with the chart paper as instructed in Section H, Scale, Pointer, and Pen Lineup.

DRIVE CORD CLUTCH ASSEMBLIES

The drive cord clutch assemblies for both X1 and X2 functions, Fig. F1, are essentially the same, but parts placement varies somewhat to avoid contact with drive cords. Additionally, the size of the delrin (white) gear may vary (as well as the balancing motor pinion gear), depending upon the speed of response of the function—1/3 or 1 second.

To remove the clutch assembly, first take off the drive cord on the function being disassembled. Where a drive cord interferes with removal of the adjacent clutch assembly components, simply loosen the take-up pulley to provide sufficient slack, or slip the drive cord off the take-up pulley altogether.

Then loosen the setscrew in the collar of the drive cord pulley, back off the retaining nut from the end of the drive cord pulley bushing and remove:

For X1—keyed washer, spacer bushing, drive cord pulley, spring washer, a second keyed washer, and delrin gear.

For X2—keyed washer, drive cord pulley, spring washer, spacer bushing, keyed washer, and finally the delrin gear.

To replace the components, reverse the above procedure. Note that the setscrew of the drive cord pulley must engage the groove of the drive cord pulley bushing. Adjust for the proper slippage by following the procedure outlined in Section G, Drive Cord Clutch Adjustment. Then tighten the setscrew securely.

INPUT MODULE

The input module is secured to the recording module by a mounting screw, Fig. C1. Before attempting to remove the input module, first make sure all power is turned off. Next, loosen the screws that hold the lower plug-in cable connectors and terminal board in position and disconnect these cables; also the upper cable, Fig. F3. Then loosen the screw holding the ink bottle holder in position and slide the holder back and up in its slot and retighten the retaining screw. Finally, using a screwdriver, back out the mounting screw and lift the module from the chassis.

In addition to the mounting screw, a small flange on the side of the chassis side plate also provides support for the input module. When replacing the module, make sure the module rests on this flange before tightening in position.

PRINTED-CIRCUIT MODULES

Three or four printed-circuit modules per function may be included

in the instrument, depending upon how the instrument is equipped. All models—both AZAR type and fixed span—have an input card, a preamplifier (see Fig. F4), and a high-level amplifier, Fig. F3, also referred to as the main or post amplifier. All fixed-span models have, in addition, a span card, Fig. F4, which is mounted directly behind the ink bottle holder on the input module.

The amplifier, preamp, and span card are replaced in the same manner, i.e., by pulling out to remove and pushing in to install. The preamp, however, in addition to the plug-in connector, also has nine (for AZAR type) or ten (for fixed span type) push-on wire connectors. Moreover, four screws secure it in position. The input card has no plug-in connector, but employs push-on wire connectors throughout. The push-on wire connectors are removed simply by pulling off. To install, just push back on until firmly seated. Observe color coding of wires removed for proper replacement, as indicated in Fig. F4. Two screws hold the input card in position.

Whenever handling one of these units, always hold by the card itself or by the card handle, if provided, never by components on the card. All plug-in cards are polarized so that insertion can be made in the correct manner only. However, when replacing individual push-on wire connectors on the input card and preamp, be sure to observe color coding of connector leads as indicated in Fig. F4.

Make sure all connectors—wire push-on as well as card connector—are firmly seated before applying power to the instrument.

MOTORS

Before replacing a motor, make sure that the failure is not due to loss of voltage at the motor terminals or to any binding. In chart motors, check for binding by turning the chart drive roll thumbwheel, Fig. A1. If the gears bind, slightly loosen the screws that hold the motor in place. Reposition the motor so that the drive gear meshes with the other gears without binding. Then retighten the screws.

Chart Motor(s)—One or two standard type chart motors (1"/hr—480"/hr) may be supplied. These motors are mounted to the front crossplate on the chassis, as indicated in Fig. F3. For speeds of 1800 or 3600"/hr, a larger gearhead motor is used. This motor is located below the standard types and mounts to the left side plate of the chassis. See Fig. F3. When the high-speed motor is used, the standard motor mounts in position near the center of the chassis.

To remove either type motor, first note to what terminals it is connected on the motor terminal board, Fig. A4. Then disconnect the motor leads from this terminal board. The standard motor has two leads, the high-speed type three. A large capacitor, not shown in Fig. A4, is associated with the high-speed motor only.

For the standard type, lift up the chart drive module and then back out the two screws that hold the motor mounting plate in position and remove the assembly from the instrument. See Fig. F5. Next, remove the motor pinion gear by loosening the setscrew in the collar of the gear and pulling off the gear. Then remove the two screws that hold the motor to the mounting plate and take off the motor.

For the high-speed type, remove the three screws that secure the mounting studs in position, Fig. A4, and lift the motor from the instrument. Back out the studs and then loosen the setscrews in the motor pinion gear and take off this gear.

When replacing either motor, the motor pinion gear fits flush with the end of the shaft and tightens against the flat(s) on the shaft, with collar toward motor (for full mesh contact with mating gear). Then install the motor by reversing the above removal procedure. Before tightening in position, adjust for backlash (play) but no binding, as instructed in Section G, Drive Gear Meshes.

Balancing Motor(s)—The balancing motor, Fig. F3, consists of an assembly of motor and gearhead drive. The assembly can be removed for replacement by following the procedure outlined below. The gearhead, however, cannot be removed from the motor. When either unit fails to function properly, the entire assembly must be replaced. Before actually deciding that the assembly is faulty, check motor operation as outlined in Section J, Isolation and Dead Band Tests, Balancing Motor Test, and also the motor brushes as outlined in Section G, Balancing Motor Assembly.

(1) Turn off all power to the instrument.

(2) Remove the back cover. Note color coding of wires connected to the motor terminals—red (R) to #1 terminal, black (K) to #2. Then disconnect these wires.

(3) Pull out the recording and input modules to the full extended position.

(4) Loosen the drive cord take-up pulley to provide slack in the drive cord. Then remove the drive cord from around the drive cord pulley.

(5) Back off the retaining nut from the end of the drive cord pulley bushing, loosen the pulley retaining setscrew, and remove the items as indicated under Drive Cord Clutch Assemblies, this section.

(6) Loosen the setscrews in the balancing motor pinion gear and remove this gear.

(7) Using an offset ratchet screwdriver, remove the screws that hold the balancing motor and gearhead drive to the chassis front support. Note that there is an insulating washer at each screw head (besides a plain washer and a lockwasher) to insulate the motor—right it—from the chassis. Then remove the balancing motor assembly from the instrument.

(8) Replace the assembly with an equivalent unit (see Table F1) by reversing the above procedure. The motor can be installed without regard to orientation. However, to facilitate accessibility of nameplate data when required, it is suggested that this data face upward, installed position. To replace the drive cord, see Drive Cords, this section.

CHART DRIVE BELTS

Two belts transfer energy from the chart motor(s) to the chart drive system. One is referred to as the primary chart drive belt, Fig. A4, and the other as the secondary belt, Fig. F5. The primary belt drives the chart drive roll directly. Coupled to the chart drive roll is the secondary belt. In addition to driving the reroll mandrel, this belt also drives the chart tear-off device. This device consists of a feeder roller against which an idler roller is spring loaded. Placement of chart paper between rollers, as for normal chart loading, draws the paper over the chart platen without requiring attachment to reroll mandrel. This may be found advantageous where short records of measurements must be taken frequently. Where not needed, the chart paper is attached to the reroll mandrel for continuous take-up by the mandrel.

Primary Belt—Loosen the belt take-up, Fig. A4, to provide sufficient slack and then lift from around the toothed pulleys. Replace by reversing this procedure. Tension on the belt should just be sufficient to take up excess slack without causing binding in the system. Binding will generally show up by stopping the chart drive motor.

Secondary Belt—If the idler roller, Fig. F6, is not removed, replacement of the drive belt will be facilitated. Care must be exercised, therefore, to keep the small nylon bushings in place while taking out the feeder roller. If the bushings are inadvertently removed, the springs are free to drop out and become lost. See Fig. F6. The first procedure outlined below assumes that the bushings are kept in place. If removed, also refer to the discussion that deals with their replacement.

Proceed as follows:

(1) Turn off all power to the instrument. Then remove the pens, scale, and chart paper. Lower the chart platen and loosen the belt take-up, Fig. F5.

(2) Remove the primary belt as outlined above. Then loosen the setscrews in the: primary belt toothed pulley, secondary belt toothed gear, chart drive roll (left end), and chart-advance thumbwheel. Back out the setscrews far enough so that the individual components clear the flats on the shaft.

(3) Pull off the primary belt toothed pulley. Then slide the shaft toward the right until the belt can be passed between the end of the shaft and the chassis side plate.

(4) Close the chart platen. Then raise the chart module and prop it up as shown in Fig. F6. On the right side, at the end of the chart tear-off bar, a keyhole slot can be observed. Back out the small screw that can be seen within the nylon bushing in that keyhole slot. Removal of this screw permits the feeder roller to be lowered at the right side and then pulled from the left side. Lower the shaft at the right end, support the nylon bushing at the left end, and slowly withdraw the shaft from the bushing. Removal of the shaft frees it from the belt, after which the belt can be taken out and discarded.

Replace the belt by reversing the above procedure. After installation, check chart paper lineup as well as scale, pointer, and pen lineup, as outlined in Sections G and H, respectively, under identical headings.

If the nylon bushing on either side is removed, the idler roller is free to come out and with it two springs which apply tension to this shaft. See Fig. F6. If the springs fall out, take off the chart tear-off bar by removing the single screw at each end. Bend the (cut) end of the spring so that it exceeds the diameter of the hole slightly. Then push it back inside the hole where it should stay. Check by turning the tear-off bar upside down.

Note that the two nylon rollers fitted in the undercuts provided on the idler roller must agree with similar undercuts in the feeder roller. See Fig. F6.

To install these components, start by replacing the nylon bushing on the left first. With the nylon rollers in position on the idler roller and roller properly oriented, place the right end through the keyhole slot in the right side. Then move the roller to the left, into the slotted hole above the nylon bushing. Slide the right end into position and hold it there by replacing the nylon bushing at that side. Insert the gear end of the feeder roller through the belt and into the nylon bushing. Bring up the right end adjacent to the nylon bushing and lock into position by installing the retaining screw. With springs in place, install the tear-off bar and secure with the flat-head screws.

SWITCHES

Two screws hold the switch mounting plate(s) to studs on the chassis crosspiece. For additional switch mounting plates, longer screws extend through spacers to provide the necessary separation. See Fig. D1. Up to four per function can be provided.

To remove a switch, first back out the two screws that hold the switch mounting plate(s) in position and let the plate(s) hang free. Next, note the color coding of wires attached to the switch terminals and unsolder these wires, making sure that all power has been turned off first. Then remove the two screws which hold the switch to the mounting plate. These screws terminate in a nutplate on the other side of the mounting plate. See Fig. F3. A slotted hole in the mounting plate provides for adjustment of the switch.

Install the replacement switch in the same location. Tighten the screws so that the switch is free to just slide. Place a piece of chart paper between the roller and intermediate cam. Then operate the intermediate cam to its maximum cam height. See Fig. D2.

With the chart paper still between intermediate cam and roller, rotate the switch to its maximum counterclockwise position, without bending the switch arm. Tighten the switch mounting screws. Then remove the chart paper and reactivate the intermediate cam several times. The roller should not hang up.

Whenever the intermediate cam is actuated to or from its high cam position, a click should be heard in the switch. At maximum cam height, check for .003" clearance (thickness of chart paper) between the cam and roller. Do this by trying to extend the switch arm beyond its maximum travel. A slight amount of clearance will assure proper switch operation.

After properly adjusting and securing in position, resolder the wires to the switch terminals and then replace the mounting plates in their original position in the recorder. To reset the switch operating point, see Section D, Preliminary Switch Adjustments.

For proper tensioning of the switch operating cams, when required, tighten the locking nut fully, totally compressing the spring washer, and then back off the nut one-half turn.

POWER TRANSFORMER

The power transformers are removed through the back of the case after removal of the metal shield, Fig. F3. This shield protects the amplifiers from magnetic pickup generated by the transformer(s) and must therefore be in position at all times. To facilitate the operation, only replace one transformer at a time, where applicable.

Proceed as follows:

Turn off all power to the instrument and then remove the back cover and high-level amplifiers. Loosen the two screws that hold the amplifier connector mounting brackets in position and release these assemblies through the slotted mounting holes. Also release the cable clamp from the shield by backing out the clamp retaining screw. Swing the cable toward the right, away from the shield. See Fig. F3.

Two screws hold the shield in place. One has a slotted head and the other a hex head. The slotted screw head is accessible from the top right side of the chassis between the take-up pulley mounting stud and chassis side plate.

Using a long thin-bladed screwdriver, loosen this screw about one full turn (no more). At the right side of the shield, use a wrench to back out this screw completely. Slide the shield to the right about a quarter inch and then bring it back and out.

Connections to the transformer are soldered. Note color coding of wire lead connections at the top and unsolder the individual connections.

Now back out the transformer mounting screws. With the upper connections removed, lower the transformer to note color coding of connecting wires at the bottom terminals. Then unsolder these connections and lift the transformer from the chassis.

Replace the transformer by reversing the above procedure. For confirmation of wire color coding where necessary, see Figs. J6 and J7.

SPARE PARTS

Table F1 is a recommended spare parts list for the instrument. See also Parts Catalog No. 179059.

TABLE F1-RECOMMENDED SPARE PARTS LIST FOR NUMBER OF FUNCTIONS IN SERVICE

DESCRIPTION	L&N PART NO.	NO. OF FUNCTIONS IN SERVICE 1-3	1-10
X1 Pen Assembly	054185	1	2
X2 Pen Assembly	054186	1	2
Ink Bottle	122150	1	2
Ink Cap and Tube	054270	1	2
Input Card	444841 (60 Hz)	1	2
Preamplifier Fixed Span	444896 (60 Hz)	1	2
AZAR Spans	444839 (60 Hz)	1	2
Amplifier Fixed Span	444892 (60 Hz)	1	2
AZAR Spans	444838 (60 Hz)	1	2
Drive Cord	146049 (X1)	1	1
	146051 (X2)	1	1
Drive Cord Pulleys (small)	084062	-	-
Bal. Motor/Gearhead Assembly (1/3 or 1 sec.)	017471	-	1
Lamp	026272	1	2
Chart Platen Detent U-Spring	028435	1	1
Pen Lifter Detent U-Spring	028440	1	1
Pen Reservoir Plug	106100	1	2
Extra-flexible Tube	265850	1	2
Slidewire Assembly (Measuring or Retransmitting)	012668	-	1
Slidewire Contacts	029869	1	2
Reservoir Connector	128739	1	2
Bal. Motor Brushes (Set, with springs)	030014	-	2

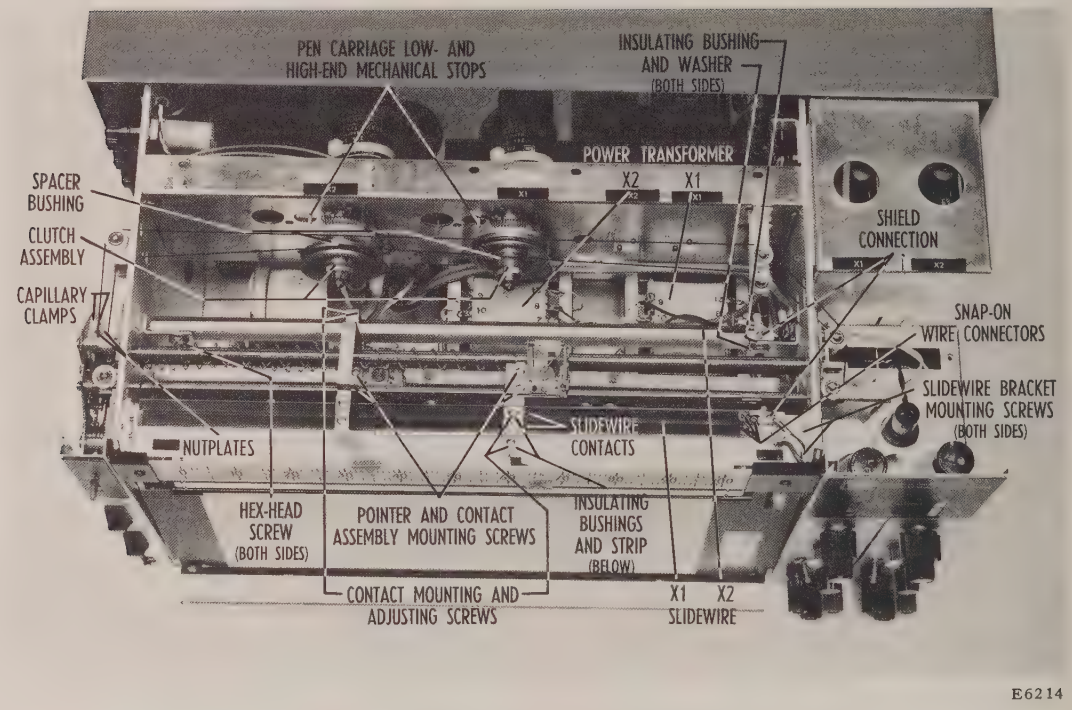
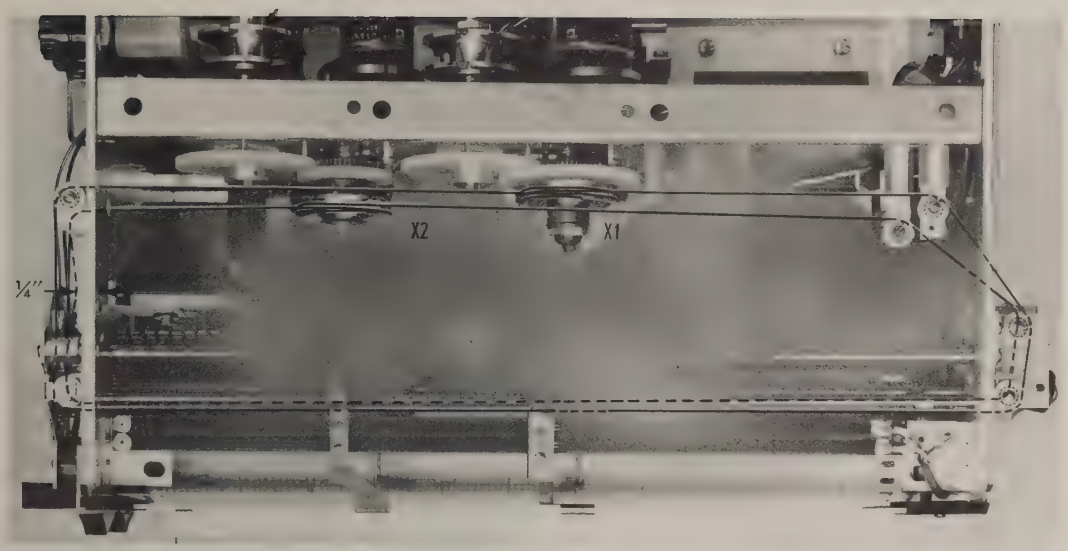


Fig. F1–Top view of recording module.



E6215

1. Turn drive cord pulley clockwise until it comes to rest against its mechanical stop and rear slot appears at 10-o'clock position.

2. Insert bead in rear slot of drive cord pulley. See text for insertion of drive cord in rear slot of X1 drive cord pulley.

3. Holding cord with left hand to apply tension to cord, rotate drive cord pulley counterclockwise with right hand until pulley is against its counterclockwise mechanical stop. Wind from rear to front without overlapping cord. Continue placing cord around other pulleys as shown.

4. Install bead at end of cord in front slot of drive cord pulley.

5. Slide take-up pulley outward to provide tension on cord. Tension as measured at point midway between side pulleys at left should be 200 grams $^{+20}_{-0}$ for displacement of cord to 1/4" as shown. Then tighten take-up pulley in position.

Fig. F2–Installation of pen drive cords.

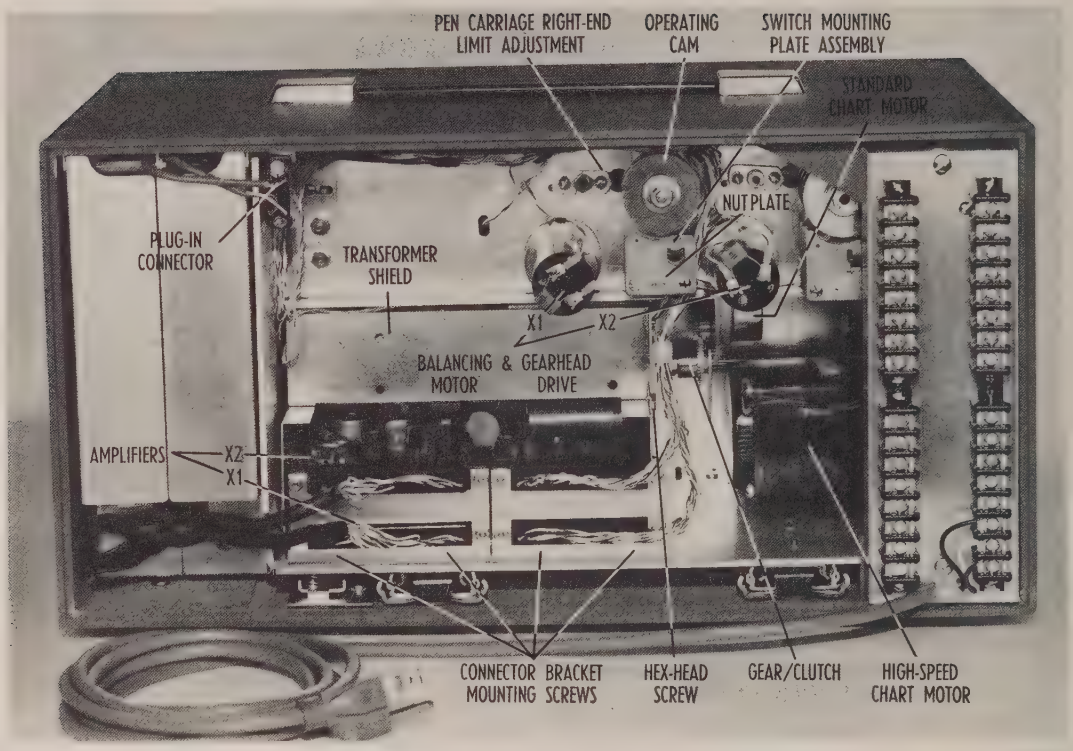


Fig. F3–Rear of case, cover removed.

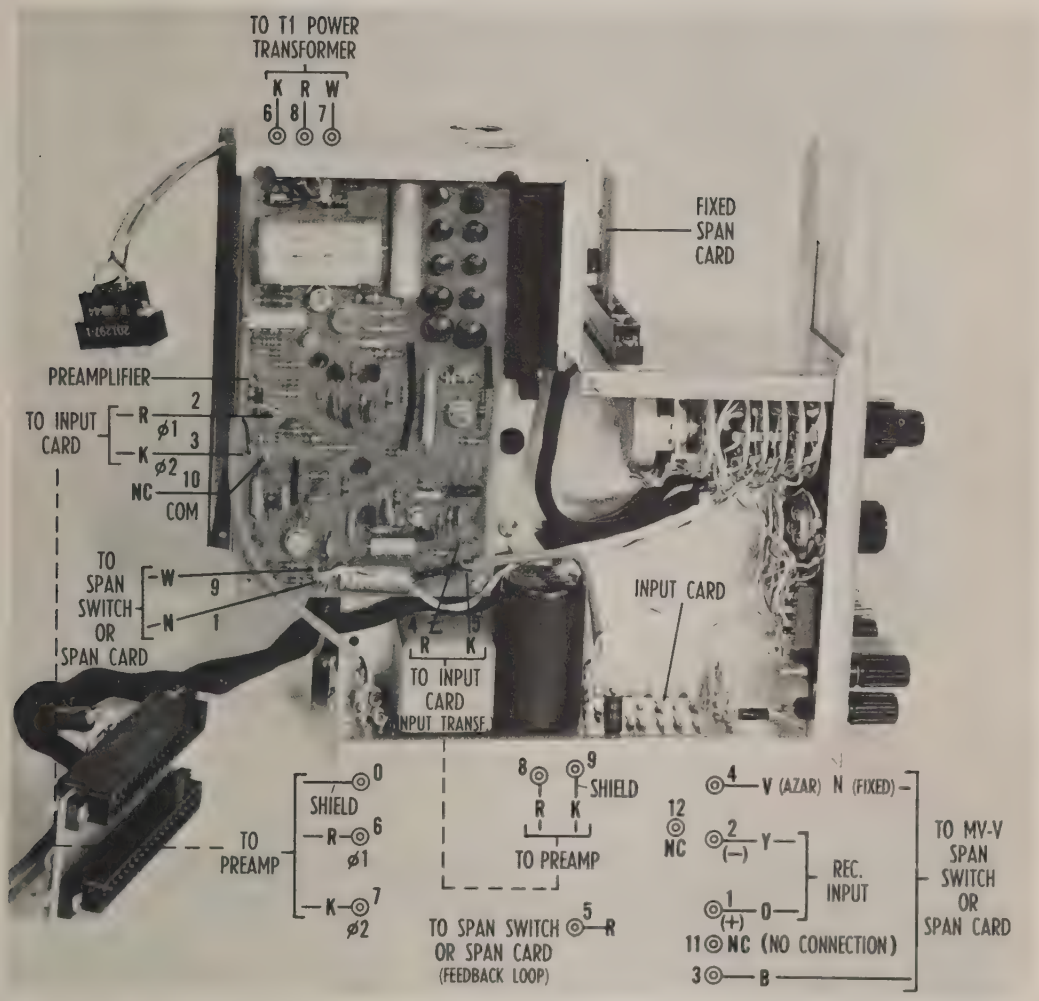
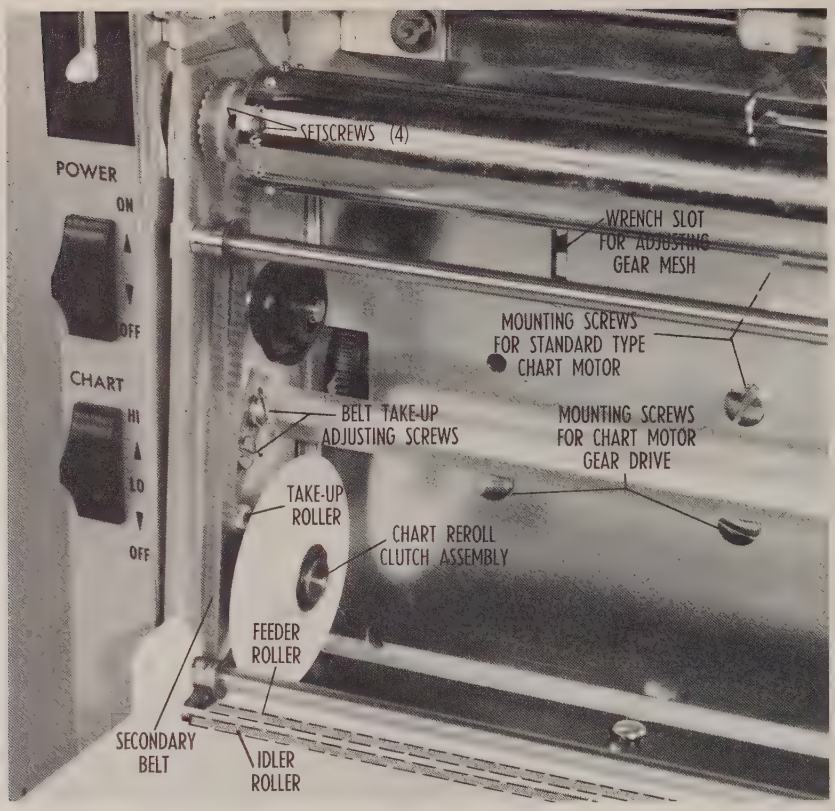
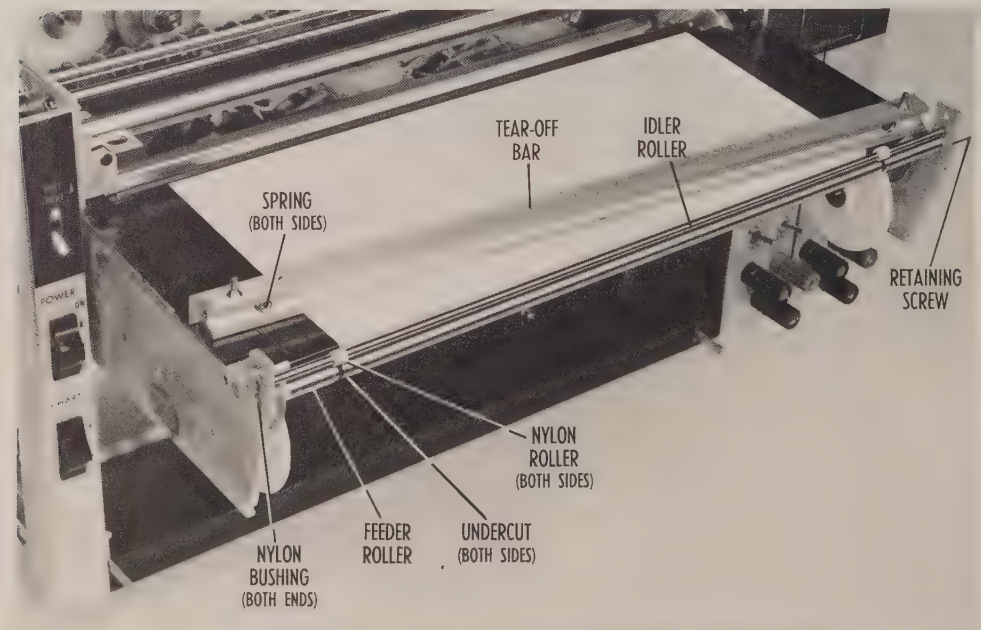


Fig. F4–Input module wiring connections. AZAR circuit shown. See also Figs. J3, J4, J6, and J7.



E6218

Fig. F5–Chart and reroll drive system. See Fig. F6 also.



E6219

Fig. F6–Chart tear-off device consisting of feeder and idler rollers. Tear-off bar removed to show components. Note relationship of nylon rollers to undercuts in feeder roller.

Section G-MECHANICAL SERVICING

CONTACT FORCE ADJUSTMENT

Each contact should bear against the slidewire with a force just sufficient to maintain good electrical contact. If the force is too low, the electrical connection will be unreliable. If the force is excessive, the contacts may wear rapidly.

The most reliable method of setting the contacts for the correct force is to measure the angle of the wiping portion of the contacts with respect to the slidewire surface, with no load applied. As shown in Fig. G1 the correct angle is 30 degrees (one-third of 90-degree angle). Bend gently where necessary, using finger pressure applied near the base of the spring contacts only.

Install the pointer and contact assembly, leaving it slightly loose so that it is free to slide. Turn the balancing motor drive cord pulley and check pointer clearance with the scale. Tighten in position when correct. While turning the balancing motor drive cord pulley, also observe tracking of the contacts from one scale limit to the other. Readjust so that they follow in the centerline of their respective resistive tracks (smooth black stripes), then tighten screws securely.

SLIDEWIRE ASSEMBLY

With all slidewire assembly mounting screws loose enough so that the assembly is free to just slide (all power off), position it by eye so that it is horizontal and about the same distance away from the pen carriage at both ends. The angle of the slidewire contacts when the slidewire assembly is properly aligned is 20 degrees, as illustrated in Fig. G1, Under Full Load. Check at both an upscale and downscale position and observe that this angle remains about the same. While rotating the balancing motor drive cord pulley to perform this operation, also check the tracking of the contacts from one scale limit to the other, as noted above for the contact force adjustment. When correct, tighten all slidewire assembly mounting screws to hold this position.

For the X2 slidewire assembly, repeat the above procedure in a similar manner.

MOTORS

The slow-speed synchronous chart motor(s) and dc balancing motor(s), except for brush replacement, cannot be repaired. If failure occurs, replace with a new one. Refer to Section F, Motors. When repair of a high-speed chart motor is found necessary, the motor should be returned to the manufacturer whose address appears on the motor nameplate.

CHART MOTOR GEAR/CLUTCH

The chart motor drives the chart paper through a gear and clutch

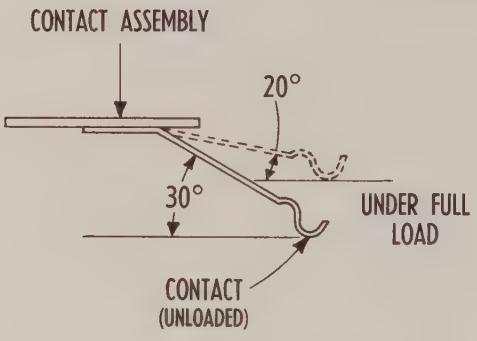


Fig. G1–Slidewire contact force measurement.

arrangement, in addition to the belt drives previously mentioned. This gear/clutch arrangement is an integral unit which consists of a gear into which a roller clutch has been fitted. The clutch and gear assembly is a type of free-wheeling or one-way rotational arrangement whereby it drives in one direction when driven, and slips in the other, when not driven. Two such arrangements are provided for two chart speeds.

The units can be tested separately by disengaging the chart motor pinion and primary belt drive. Turning in one direction should cause the shaft to rotate while turning in the opposite direction should not, i.e., the gear should rotate, the shaft remaining stationary. If operation is erratic, replace with a new gear/clutch rather than attempting to clean and relubricate the faulty unit.

To remove the drive assembly, first take off the primary belt drive gear and then remove the slow-speed motor(s). Back out the two screws that hold the drive assembly in position, Fig. F5, and lift the assembly from the chassis.

Collars and/or retaining rings hold the units in position on the shaft. Note orientation and location, and then remove the faulty unit by taking off the appropriate collar and/or retaining rings.

Install by reversing the above procedure. Allow for no perceptible end shake in the shaft and then adjust the motor for minimum backlash without binding.

BALANCING MOTOR ASSEMBLY

The balancing motor assembly consists of the motor with integral gearhead. The motor cannot be removed from the gearhead, and if either is faulty the complete assembly must be replaced. Motor brushes, however, can be replaced as follows:

Remove the motor from the instrument, as instructed in Section F,

Motors, Balancing Motor(s). Then back out the hex screw which serves as a terminal for the connecting wires. Turn the motor upside down, being careful not to lose the small springs and brushes. If the square sections of the brushes are less than 1/8" long, replace them with new ones. Reassemble the motor by reversing the above procedure, i.e., first replace the brushes and springs, as a unit, followed by the hex screws. Note that the brushes are square and bear against a flat commutator. Orientation of brushes with respect to the brush holder is therefore not necessary.

> Note: In the event that a good balancing motor is disassembled for any reason, make sure that the spacers are replaced in the end bell. Also that the notch in the motor housing lines up with the indicator mark (-) on the end cover before tightening the end cover in position. Failure to observe alignment may result in improper operation or no operation at all.

PEN ADJUSTMENTS

If the pen assembly becomes loose in its mounting, it may result in shake of the penpoint. When properly mounted, the pen will swing freely on the pivots in a vertical direction and the penpoint will bear against the chart with sufficient force to assure proper inking at all times. The flexible mounting support should exert enough force on the pivots so that there is no shake or backlash between the pen assembly and the mounting supports of the pen carriage.

To adjust for no shake of the penpoint, remove the pen assembly and bend the flexible mounting support (Fig. El) toward the rigid mounting support. The preset dimension should be 0.062 ±.010" as measured from the tip of the flexible mounting support to a line drawn parallel with the rigid mounting support from the fixed end of the flexible mounting support. After making this adjustment and replacing the pen, check to be sure that the pen functions as described. The pen bias spring must be on top of pivot support as shown in Fig. El.

Then check pen lifter operation as follows: Set the pen lifter in the up position. The penpoints should be raised off the chart paper approximately 1/16". Now lower the pen lifter. The pens should touch the chart paper and write on the chart. With the pens on the paper, check for clearance between the pen lifter cam and the tip of the setscrew at the front of the pen assembly. Readjust this setscrew where necessary to meet the above conditions.

The penpoint should bear against the chart with a force of 5-8 grams, as measured within 3/16" of the pen tip. If the force is less than 5 grams, the pen will probably skip; if it is more than 8 grams, the pen will probably pick up paper fibers and become clogged or even tear the chart. To correct for the former condition, bend the pen bias spring, Fig. El, towards the bottom of the recorder; to correct for the latter condition, bend the pen bias spring towards the top of the recorder. A

lighter force is preferable for highly active recording, a heavier force for large-excursion, high-speed type recording.

DRIVE CORD CLUTCH ADJUSTMENT

This clutch, Fig. F1, serves as a shock absorber when the mechanical balancing system is driven to either low- or high-end mechanical position.

The clutch should not be set so tight that the delrin (white) gear is locked to the shaft. Adjust the clutch so that when the pen is driven against either stop position, the delrin gear will slip and the motor will continue to drive at only slightly less than the normal free-running (sluing) speed. The correct motor speed can be determined by measuring the motor voltage while it is driving against the end stop. The voltage should be between 15 and 20 volts.

CHART PAPER LINEUP

After the chart drive roll has been loosened, as is required for replacement of the secondary drive belt, it must be correctly reset for proper tracking of the chart paper.

To reset the roller, start by first installing the chart as is normally done. Make sure that the left edge of the paper just contacts the flange of the chart reroll clutch assembly, because this flange acts as a reference point. With the holes in the paper over the pins in the drive roll, apply tension on the paper by turning the drive roll thumbwheel. Observe the paper as it is drawn tightly. There should be no distortion at the pins. Adjust the drive roll until the above condition is satisfactory. Then tighten the setscrews against the flats on the shaft. All flats correspond with those at the left end.

DRIVE GEAR MESHES

Adjust for minimum backlash and no bind. Check at several points around a gear to be sure there is no binding at any point.

Section H–CALIBRATION

This section outlines proper procedures for checking calibration accuracy of the Speedomax instrument. An accuracy check will be required when measuring circuit components are disturbed—e.g., after removal and replacement of a measuring slidewire, installation of new slidewire or slidewire contacts, replacing or repairing of an amplifier, etc. The user may also wish to check the calibration periodically.

PRELIMINARY

Before proceeding with the calibration check, perform the following checks and adjustments. Make sure that the instrument has warmed up for at least 30 minutes; and for thermocouple measurements it is advisable to wrap the incoming wires directly around the input terminals of the reference junction module and tighten securely.

In addition, be sure the factory adjustments have not been disturbed (see Section J, Factory Adjustments, if required) and there is no dead band (also indicated in Section J under Isolation and Dead Band Tests, Dead Band Test).

SCALE, POINTER, AND PEN LINEUP

During the following checks, the instrument should be turned off and the recording module left in the out position.

Rotate the drive cord pulley to move the pen to the left until the penpoint is on the first calibrated line of the chart grid. Under this condition the pointer should be on the first calibrated line of the scale. Then rotate the drive cord pulley until the mechanical stop in the left direction is reached. The pointer should now be on the dot to the left of the first calibrated line on the scale.

If the instrument does not meet the following requirements, correct the line up as follows:

(1) Using a suitable straightedge, align the sub-zero dot on the scale with the sub-zero line on the chart paper grid. Adjust the scale if required by first loosening the scale retaining screws, aligning the scale as outlined above, and then retightening the retaining screws.

(2) Rotate the drive cord pulley to move the pen to the left until the penpoint is on the first calibrated line of the chart paper grid. Adjust the pointer so that it is on the first calibrated line of the scale. Adjust by loosening the pointer retaining screws, moving the pointer the required amount, and then retightening these screws.

(3) Rotate the drive cord pulley until the penpoint is on the sub-zero line of the chart paper. The pen carriage should be stopped at the low- or left-end. Adjust by loosening the drive cord clamping screw, Fig. E1,

repositioning the carriage as required, and then retightening the clamping screw to hold this position.

(4) Rotate the drive cord pulley to move the pen upscale (right end) until the pointer is approximately 1/16" above the last calibrated line of the scale. Adjust the high-end pen carriage stop, Fig. F1, by loosening the two screws that hold this stop assembly to the chassis, repositioning the movable arm as required, and then retightening the retaining screws. See Fig. F3 also.

CALIBRATION PROCEDURE

Table H1 lists Leeds & Northrup potentiometers suitable for calibration purposes. The smaller the limit-of-error listed the better the accuracy of measurement. Wherever possible, therefore, the calibration of the Speedomax instrument should be checked with a potentiometer whose accuracy and resolution are several times better than the instrument being checked since the validity of the check depends upon how accurate the reference value is known. Such reference potentiometers include the Cat. 8686 and 8687, 8690 and 8691, and any in the Cat. 7550 Series listed.

However, in many cases a reference potentiometer of less accurate means is adequate and the expense of a more precise unit not warranted. An instrument that falls within this category is the Cat. 8696 listed. In this type of potentiometer the accuracy of measurement can be improved if the potentiometer is first checked against one of the standard types (7554, 7555, 8690, etc.) and a calibration curve developed. In this way, the error or deviation can be taken into consideration and the Speedomax instrument checked with a higher degree of accuracy than would be possible without the aid of the calibration curve.

It should be noted that in the Cat. 8696 potentiometer listed, the limit-of-error, stated in terms of percent of span, applies only when the span of the instrument being checked is the same as that of the checking potentiometer. If the span of the instrument being checked is smaller than that of the checking potentiometer, the limit-of-error increases. For example, if the range of the checking potentiometer is 0 to 22 mV, or a span of 22 mV, 0.3% of 22 mV equals 0.066 mV. Thus, the error is ±0.066 mV, applicable at any point within this range. When applied to a recorder range of, say, 0 to 5 mV, the error amounts to 1.3% at 5 mV and to 3.3% at 2 mV for a 0 to 2 mV range.

From this it can be seen that wherever feasible, the span of the checking potentiometer and that of the instrument being checked should be the same or nearly so. The above does not apply to reference potentiometers where the limit-of-error is stated in percent of reading. In this case the error as a percent of reading applies, as indicated.

To calibrate the instrument, follow either procedure (1) or (2) as outlined in Section C, Range/Span Adjustments, depending upon span or range to be checked.

With the instrument set up for a particular range, apply a millivolt input from a reference potentiometer, equal to the upper range limit. That is, 5.6 mV or 30.7 mV, using the examples cited in Section C. The measuring pointer should come to balance at 100 on the scale, within the combined accuracy of both instruments. Similarly, with 1.1 mV or -9 mV input, the measuring pointer should come to balance at zero on the scale, within the combined accuracy of both instruments.

Check the 100-microvolt, 100-millivolt, and 1-volt spans for an accuracy of ±0.25% of span or ±2 microvolts, whichever is greater.

Check the ZERO knob for ±100% of span adjustment.

Check the SPAN TRIM knob for a 2.5:1 ratio minimum by setting the SPAN switch to V, SPAN SET dial to 2, and Zero at left-end of scale. With 0.8 volt or less input applied to the recorder, turn the SPAN TRIM knob fully clockwise. The pointer should read at 100% of scale.

If the Speedomax instrument does not meet the required accuracy, refer to Sections J and K. Calibration errors may be due to inadvertent readjustment of a factory calibrated potentiometer, or a regulated power supply or other electrical circuit may be faulty.

TABLE H1–LEEDS & NORTHRUP EMF REFERENCE POTENTIOMETERS

Cat. No.	Description	Ranges	Limits of Error△
7554 7554-1*	Type K-4, guarded	3	±(0.005% of reading + 20μV)
7555 7555-1*	Type K-5, guarded	3	±(0.003% of reading + 3μV)
7556 7556-1*	Six-dial, guarded	3	±(0.0005% of reading + 1μV)
7564 7564-1*	Differential Type	6	50-150 ppm, depending upon range
8686 8686-1**	Portable, millivolt	1	±(0.03% of reading + 3μV)
8687 8687-1**	Portable, volt	2	±(0.03% of reading + 30μV)
8690 8690-1**	Portable, millivolt	1	±(0.05% of reading + 15μV)
8691 8691-1**	Portable, millivolt	2	±(0.05% of reading + 150μV)
8696	Portable, millivolt	2	±(0.03% of span)

* Designed for rack mounting.

** Designed for rack mounting, line operation, and is provided with multiple input terminals and selector switch.

△ Figures listed are for highest range where applicable. Limit of error diminishes on lower ranges.

Section J–LOCATING TROUBLE

In some cases of faulty instrument operation, the source of trouble will be immediately apparent. In others, this will not be the case since a given symptom may often be due to any one of several causes. In locating and eliminating such faults, two methods are recommended:

(1) When trouble arises, a number of simple preliminary checks, listed later in this section, should be made before proceeding with more elaborate tests. These simple checks are designed to detect or correct those troubles most likely to occur.

(2) If the trouble is not located or remedied by the simple preliminary checks, a series of tests, following the preliminary tests, can be used to isolate the fault to one of the major sections of a function. When this is done, the faulty section can then be checked systematically to locate the particular component causing trouble.

INTERFERENCE*

Introduction—Interference is any electrical energy in the instrument's circuits which limits the precision with which the desired signal information can be discerned. "Noise", "pickup", and "hash" are other terms for various forms of interference. Good instrument design demands that internal interference generation be minimized and that adequate protection be provided for expected levels of external generated interference. The Speedomax recorder design meets these requirements. However, external interference sometimes is severe enough to require extra protection of the signal circuits. The various ways that such interference can enter the instrument's signal circuits, and methods for interference control, are described in the following paragraphs:

From the point of view of recorder performance, interference is of two types: (1) that which produces balancing motor torque and thus causes a shift in instrument calibration; (2) that which produces no motor torque but overloads the amplifier, causing sluggish operation and excessive dead band. Both types of interference may exist simultaneously, resulting in a combination of these effects. In addition, if the interference source is variable or intermittent, the adverse effects will also be of an erratic nature.

> NOTE: The symptoms described above also may be caused by failure of transistors, filter capacitors, etc., on printed-circuit modules in the recorder. If such symptoms are observed, the modules should be eliminated as a source of trouble before any further steps are taken. This is most conveniently done by replacing with ones known to be good and observing whether the performance is corrected.

* Portions of this section are taken from ISA Journal dated April, 1960, "Solving Pickup Problems in Electrical Instrumentation". Printed with permission of the publishers.

Causes—The more usual forms of interference occur in four frequency bands:

Direct Current—Direct current interference is generally produced by thermoelectric and corrosion voltages. Thermoelectric voltages, also known as thermal voltages, can arise whenever junction points of different materials in a measuring circuit are exposed to temperature differences (Peltier effect). Corrosion voltages occur in a measuring circuit because of voltaic action between dissimilar materials exposed to an electrolyte. Although measuring circuits are normally designed to be free of electrolytes, metallic corrosion combined with a humid atmosphere can produce effective electrolytes and resulting corrosion voltages.

Low Frequency—Because low-frequency interference is in the same part of the frequency spectrum as the measured quantity, it is difficult to distinguish from the normal signal. It is usually introduced by inductive or capacitive coupling from ac or dc power circuits in which switching occurs. In high-impedance circuits, movement of shielded cables is a common cause of low-frequency interference.

Power-Line Frequency and its Harmonics—The most frequently encountered interference is of power line frequency—50 or 60 Hz. Sometimes the lower harmonics of the power line frequency, e.g., 100 or 120 Hz, also appear as interference. These frequencies can be troublesome because the recorder preamp converts the dc input signal to an ac signal for drift-free amplification. The converted signal also contains harmonics of the ac frequency which the amplifier must pass. Ac interference, therefore, may be amplified along with the measured signal to produce errors.

Radio Frequency—Radio frequencies (rf) extend from tens of kilohertz to hundreds of megahertz. Although most dc measuring instruments, including the Speedomax recorder, cannot respond directly to such high frequencies, interference can be caused in such instruments by transient or modulated rf energy. Many common industrial devices produce rf energy of this kind—induction heaters, arc furnaces, ignitrons, and arcing contacts are examples. Powered by unfiltered ac or intermittent pulses, their modulated rf outputs can be coupled to signal circuits and demodulated in the instrument producing interference effects similar to power-frequency interference or low-frequency transients.

Coupling to Instrument—For interference to affect performance, its source must be electrically coupled to the instrument's measuring circuits—conductively, magnetically, capacitively, electromagnetically, or by a combination of these. For clarity, each of these coupling mechanisms is discussed below in terms of the thermocouple instrument shown in Fig. J1. The same considerations also apply when other types of sensors are used.

Conductive Coupling—The metal of the thermocouple well, vessel, and structural supports usually are grounded as shown in Fig. J1. In many installations, the thermocouple is intentionally connected to its well, while in others, insulation resistance between thermocouple and well may be low.

Either situation causes a conductive path from thermocouple to ground, symbolized by dashed resistor R1. In addition, the instrument itself usually has two separate connections to earth. One: by connection of the instrument case to a metal panel connected to a nearby earth point, indicated by the triangular ground symbol. Two: through the ac power line, usually with one side grounded adjacent to the distribution transformer, indicated by the "rake" ground symbol. These three ground connections are usually not made to the same earth point. Thus, due to earth currents, either ac or dc potential differences can exist between the pairs of earth connections, and these differences often are large compared to the thermocouple output voltage. Furthermore, in the signal circuit between the source (thermocouple) and the instrument, insulation of the measuring circuit from ground is not perfect. Therefore, unavoidable leakage resistances exist between the various parts and their local "grounds", indicated in Fig. J1 by dashed resistors R2 and R3. These paths to earth form circuits with potential differences which cause interference currents to flow through the measuring circuit's components (see arrows), thus producing error voltages.

Magnetic Coupling—Magnetic coupling, Fig. J2, essentially is transformer action between the interference source and the measuring circuit. If the measuring circuit is located close enough to an ac motor or transformer so as to link with its magnetic field, an alternating voltage can be induced in the measuring circuit wires and resistors which can cause disturbances or errors in the measurement. Also, the power supply to the motor or transformer can be the source of a magnetic field coupling with the measuring circuit.

Inductive coupling produces voltages only during changes in the magnetic field. However, magnetic induction is not limited to alternating current sources. Even a dc circuit produces a changing magnetic field when the current starts or stops, i.e., is periodically or intermittently interrupted, as indicated symbolically by the switched dc circuit in Fig. J2.

Capacitive Coupling—Capacitive coupling, also referred to as electrostatic coupling, usually is associated with leakage paths to ground. However, these paths are capacitive rather than conductive. Capacitive paths generally dominate the leakage impedances since the leakage resistances are usually higher and easier to control than the capacitive reactances, especially for power frequencies. Capacitive coupling, therefore, is the more common problem.

In Fig. J1, the measuring circuit has capacitance to the grounded instrument case through C2. The element whose temperature is being measured is commonly connected to ground as noted above, and the sensor, when not solidly connected to it, often has considerable capacitance to the grounded measured element, as shown by C1. In some cases an electrically heated insulated element will have substantial voltage to ground via capacitance to the grounded ac heating circuit. Additionally, the external measuring circuit leads have capacitance to ground, as indicated by C3.

These capacitive paths to various "grounds" form circuits including parts of the measuring circuit and also including alternating voltages. Thus, alternating currents can flow in parts of the measuring circuit, causing error voltages. Furthermore, transient interference disturbances can be coupled into the measuring circuit by capacitance between it and other circuits normally carrying dc. When switching disturbs voltages in the dc circuit, the changing voltages, acting like alternating voltages, produce momentary interference current flow through the capacitive coupling paths and through the measuring circuits.

Electromagnetic Radiation Coupling—Significent coupling by electromagnetic radiation occurs only at radio frequencies. An unshielded conductor carrying rf current radiates rf energy, and another unshielded conductor can absorb energy from the radiated field. Thus, interfering modulated rf energy can be transferred to wires which will carry this interference to inadequately protected signal circuits where it can produce errors.

Types of Interference—The four types of interference coupling discussed above cause interference to be applied to the measuring circuit in one or both of two modes:

Differential- or Normal-Mode Interference—This type of interference is also called "series-mode", "opposed-mode", or "transverse". It directly impresses a potential difference between the input terminals of the instrument in the same manner as a legitimate signal. For example, differential-mode interference would appear as a voltage in series with terminals A and B and the thermocouple in Fig. J1. (In current measurements, differential-mode interference would act as an interference current generator in shunt with the measured current source.)

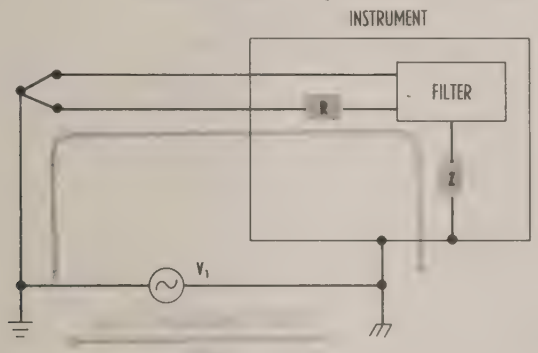
Differential-mode interference acts directly on the instrument because its full magnitude is developed in the measuring circuit. Ac differential-mode interference is seldom a problem in Speedomax recorders because the input filters have high attenuation at power and higher frequencies. Dc differential-mode interference, e.g., thermal emf's, can usually be prevented by using proper materials in the signal circuit. Transient differential-mode interference due to cable flexing sometimes is troublesome in high impedance measuring circuits, but can be overcome by using low noise cables with adequate mechanical support.

Common-Mode-Interference—This type of interference is sometimes called "longitudinal" or "in-phase" interference. It causes both instrument input terminals to change potential simultaneously and by the same amount relative to ground. It is injected into the signal circuit by sources having one terminal grounded and the other coupled to the measuring circuit, capacitively or conductively.

Common-mode interference acts indirectly on the instrument; a part of the common-mode energy incident on the measuring circuit must be converted to differential-mode interference to affect the measurement. Conversion

to differential-mode interference results from common-mode currents that are caused to flow through impedances of the measuring circuit. The efficiency of conversion is generally small because the leakage impedances through which the common-mode source is coupled to the measuring circuit usually are large compared to the impedances in the measuring circuit. However, the magnitudes of many common-mode sources are much greater than the magnitudes of the measured quantities, so that common-mode interference can seriously affect inadequately protected instruments in spite of the low conversion efficiency. Common-mode interference problems, therefore, are more prevalent and more troublesome than differential-mode interference problems. The following example illustrates this point.

Example: If: $Z = 2 \times 10^6$ ohms, $R = 100$ ohms, and $V_1 = 5$ volts ac, then $Z + R$ = approximately 2×10^6 ohms.



R = Example of a part in the measuring circuit.
Z = High impedance between case and measuring circuit.
V_1 = Longitudinal interference voltage.

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Interference current I_f = 5 volts/2×10^6 ohms
= 2.5×10^{-6} ampere
= 2.5 microamperes

Therefore, the differential-mode voltage produced across
R = 100 ohms x 2.5 microamperes
= 2.5×10^{-4} volt or 0.25 millivolt.

On a 10-millivolt span this undesired voltage can be a large error depending upon the attenuation of the filter. Ac common-mode interference is generally more troublesome than dc common-mode interference because of capacitive leakage. Common-mode ac interference is usually attributable to (1) primary element and instrument case at different ac ground potentials, or (2) primary element capacitively (or conductively) coupled to an ac voltage or current source. Interference can also originate in the 120V ac supply to the instrument. This condition is particularly likely when the power line is not grounded near the instrument or has a ground reference different from that for the instrument case or primary element. Interference entering the system from the power supply is indistinguishable

in its effects from that entering through the primary element circuit.

Remedial Action—Techniques for suppressing interference are: (1) physical isolation, (2) shielding, (3) magnetic loop reduction, (4) grounding and (5) filtering. These techniques have been used in the Speedomax recorder to eliminate internally generated interference and also provide substantial protection from external interference. Where very severe interference exists, however, application of the techniques to the external parts of the measuring circuit may be required.

Physical Isolation—Physical isolation between power and signal leads or between high-signal-level and low-signal-level leads provides substantial protection in many situations. A few inches separation of wires or circuit elements often is sufficient to reduce capacitive or magnetic coupling to acceptable levels. Removal of power wiring from signal circuit conduits or raceways is usually effective for control of interference from this source.

Shielding—Appropriate shields can prevent interference coupling to measuring circuits by any of the coupling mechanisms described. However, shielding requirements are different for the different kinds of coupling.

Electrostatic Shields—These can be effective against both capacitive coupling and conductive coupling of interference. Electrostatic shields must have low resistance relative to the measuring circuit, and be properly connected to it or to ground (not both connections for a single shield). These shields exist in solid form and in braided or woven form, and may be either metallic or conductive plastic. Solid shields are the most effective, although braided or woven types are often adequate. The latter provide flexibility for cables, and are almost always metal. Their effectiveness depends on the closeness of the weave or braid, being better for greater coverage. Conductive plastic shields provide flexibility as well as complete coverage, but generally have greater resistance than metal shields. They are effective for high impedance measuring circuits.

In general, shields should be covered with an outer layer of insulation to prevent accidental contact with other shields, circuits, or ground. Such contacts can destroy the effectiveness of the electrostatic shield.

Magnetic Shields—These prevent magnetic interference coupling to measuring circuits. They must have low reluctance relative to the air path through the measuring circuit. Shield connections do not affect magnetic shielding properties, but such shields are metal and with appropriate connections they can also provide some electrostatic shielding. Good magnetic shields are always solid and, in general, their effectiveness increases with their thickness. Different magnetically soft alloys provide optimum shielding for different levels of interference field strength.

Magnetic Loop Reduction and Transposition—The voltage induced in a circuit by a changing magnetic field is directly proportional to the net

area of the circuit loops which enclose the field. Thus, bringing the conductors of a measuring circuit as close together as possible at all points will reduce magnetically-coupled interference. Transposition or twisting of the measuring circuit leads where possible will further reduce magnetic interference coupling to the measuring circuit. Transposed or twisted leads provide adjacent areas equal in size but with conductors reversed so the induced voltages cancel. This principle is used in wiring throughout the recorder.

Grounding—The objective of grounding is the elimination of interference current flow through measuring circuit impedances due to grounded interference sources (common-mode sources). However, unless grounding is properly carried out, ground connections themselves can couple ground potential differences to the measuring circuit causing interference current flow. To avoid this and meet the desired grounding objective, no more than one ground connection can be made from the measuring circuit. This applies also to ground shields where used. Since the instrument case and power line (L2) generally should be grounded, a grounded transducer requires at least one shield on the measuring circuit, grounded at the transducer end only, so that any ground potential difference causes current flow in the shield but not in the measuring circuit. Where more than one common-mode interference source exists, multiple shields may be required, each with only a single connection to ground or other appropriate circuit point.

If possible, the instrument case and the L2 side of the line supply should be connected to the same ground potential. If the supply line conditions do not permit this, the addition of an isolation transformer in the line will permit such grounding.

Where a properly designed instrument grounding system is not available, the best form of grounding is a cold-water pipe having an extensive underground system. Connection to the pipe should be as near its emergence from the earth as possible. Ground rods and other devices such as buried wires or objects, steam and gas pipes, etc., may not be as good, depending upon soil conditions and joint resistances. Because of the widespread use of plastic and other nonconductive forms of piping, the ground point should be checked for continuity to earth before considering it a good ground.

Filtering—Filters can act only on differential-mode interference. Properly designed filters prevent normal amounts of interference coupled into the measuring circuit from degrading instrument accuracy. Filtering action in the Speedomax instrument is accomplished by combination networks in the input card and post amplifier, including a twin-T in each, that provide a high degree of interference protection.

Eliminating Interference—If the instrument exhibits the faulty performance effects described earlier and the amplifier has been eliminated as a source of trouble, proceed as follows:

(1) Check to be sure all connections have been made in accordance

with Section A. This includes input wiring connections and the inclusion of an isolating transformer, if required, to ground the L2 side of the line supply.

(2) Check for a good single-point ground, as described above. Multiple grounds on the measuring circuit can be found by disconnecting the intended ground and rechecking for continuity to ground.

(3) Check for objects placed within the instrument case that could possibly ground the balancing motor or slidewire, or parts of the amplifier, preamplifier, or input or span card.

(4) Check the path of the input wires to be sure there is adequate separation from any motors, transformers, belt drives, ac and dc power lines, and ac or dc high-level signalling circuits.

(5) If the foregoing checks do not disclose the cause of the interference, application of some of the above remedies to the external measuring circuit may be required.

PRELIMINARY CHECKS

Before proceeding with the more complicated isolation tests, follow the simple checking and replacement procedure given in Table J1. These steps will rapidly locate or remedy the great majority of instrument faults. All factory adjustments are assumed to be set correctly.

Since repair of printed-circuit modules is not recommended, spares should be kept on hand. If desired, faulty modules can be returned to Leeds & Northrup Company for repair. Table F1, Section F, lists the number of spare parts to be kept on hand for the number of functions in service. If the Speedomax instrument has more than one amplifier or preamp, it is a simple matter to temporarily interchange corresponding printed-circuit modules to find the faulty one, and then replacing it.

Where instrument operation is acceptable but calibration is off, the factory settings may have inadvertently been disturbed. In this case, refer to Factory Adjustments at the end of this section.

ISOLATION AND DEAD BAND TESTS

If the trouble has not been located or corrected by the simple preliminary checks, the tests given here will isolate it to one of the three major sections of each function: (1) The measuring circuit, (2) the amplifier or preamplifier, or (3) the balancing motor circuit.

The recorder amplifier and preamplifier can easily be isolated as sources of trouble by applying the following tests.

Overall Test—Short the recorder input terminals and readjust the zero knob on the input module. The measuring pointer should move upscale and

TABLE J1

SYMPTOM	RECOMMENDED CHECKS AND REPLACEMENTS
1. Instrument is completely inoperative including chart motor or motors.	Replace line fuse. If new fuse blows immediately, refer to 3 below. If fuse is good, check line voltage across terminals L1 and L2 of main terminal board.
2. Line supply and fuse are good but there is no balancing action.	Examine amplifier fuse and all printed-circuit module and plug-in connectors for contacts that may not be making contact. Check terminal boards for loose screws. Replace amplifiers and preamplifiers with ones known to be good. Test all measuring circuit wiring for continuity.
3. Line fuse blows when replaced.	Turn off main power and chart motor switch if one is present. Check power circuit wiring for possible shorts. If none are found, replace line fuse and turn on power switches one at a time until fuse blows. Trouble is probably in the circuit that was turned on last. If amplifier fuse blows when amplifier is turned on, isolate the balancing motor from the amplifier by disconnecting the balancing motor leads from the motor. If a new fuse still blows, trouble is in the amplifier or power output transistors; if not, trouble is in the balancing motor. Test for shorts between all motor leads and case ground. If the fault cannot be easily repaired, replace the defective part with a known good one.
4. Response is sluggish and/or dead band is excessive.	With instrument energized, manually move pen carriage about 1/2" upscale and slowly allow it to return to balance point. Note balance point. Repeat above procedure moving pen carriage downscale. If dead band is excessive replace amplifier and preamplifier with known good ones. Also check all drive cord ball bearing pulleys.
5. Operates erratically, oscillates, or overshoots balance point.	Check all connections to printed-circuit cards, terminal boards, and primary element.
6. Operation appears normal but scale reading is in error.	Check calibration of primary element. Check instrument calibration.

downscale for corresponding movements of the ZERO knob, i.e., clockwise rotation for upscale movement, counterclockwise rotation for downscale movement. Remove the input short.

Preamplifier and Input Card—Connect a reference potentiometer to the recorder input terminals and initially set it for zero input. Set the SPAN switch to MV and the SPAN SET dial to any convenient value for the adjustable span module, or install a millivolt span card for the fixed-span type. Using a volt-ohm-milliammeter set to measure volts, connect the negative lead to the negative (-) input terminal and the positive lead to pin 13 on the preamp plug-in connector, or to the K-R (black-red) lead which goes to the MV side of the SPAN MV-V switch. Adjust the reference potentiometer for fullscale travel of the measuring pointer, e.g., 1 mV for 1 mV span setting or span card. The voltmeter should read two volts with fullscale input of 1 mV and zero with zero input. If it does, the preamp and input cards are good.

Amplifier Only—With the reference potentiometer still connected to the recorder input terminals, snap the SPAN switch to V, and set the ZERO switch to OUT and the SPAN SET dial to any convenient value for the adjustable span module, or install a volt span card for the fixed span type. Disconnect the leads from the balancing motor and adjust the pen to the center of the scale. Now connect a dc voltmeter across these leads. Apply a voltage to the input of more than half the span selected. The voltmeter should read a minimum of 18 volts in one direction. Reducing the input voltage to less than half the span should cause the output to go to 18 volts minimum in the opposite direction. If the voltage is obtained as indicated, the amplifier is in working order.

Balancing Motor Test—The balancing motor can be tested simply by disconnecting the leads at the motor terminals and placing a low dc voltage across the motor terminals (18V max.). The motor should run in one direction. Reversing the leads should cause the motor to run in the opposite direction.

If the motor runs as stated, the trouble is in the amplifier or preamplifier, or the measuring circuit. If it does not, the balancing motor is at fault. Check continuity across the motor terminals. Resistance between terminals with rotor blocked should be 11 ohms nominal. Between each terminal and motor housing, resistance should be infinite. Replace the defective component where necessary.

Dead Band Test—The dead band for each function should be 0.10% or less of fullscale reading. If not eliminated, dead band appears as a calibration error.

Dead band can be defined functionally as the difference between the final scale readings for upscale and downscale approach to balance, respectively, the measured quantity being the same in each case. Thus dead band is measured by displacing the scale reading, first in one direction and then in the other, and measuring or observing the difference between

the two balance points.

Two methods are suggested. One requires the use of a precision reference potentiometer such as a Leeds & Northrup Type K Potentiometer, or equivalent (see Table H1); the other is a field check which simply makes use of manual displacement of the measuring pointer and pen. If a precision potentiometer is available, the Potentiometer Method is to be preferred because it is the more accurate of the two methods. Where dead band exceeds the limits stated, replace the preamp and/or amplifier, or test these units as outlined in Section K.

Potentiometer Method—Proceed as follows:

(1) Disconnect the usual input leads and then connect the reference potentiometer to these same input terminals, observing polarity.

(2) Standardize the current of the reference potentiometer.

(3) Short-circuit or clamp the galvanometer of the reference potentiometer to eliminate spurious voltages which would be produced by motion of the galvanometer coil.

(4) Set the reference potentiometer to a value near midscale so that both pointer and pen are directly on a line of the chart paper.

(5) Change the setting of the reference potentiometer until the instrument indication is greater than the original value by an amount equal to approximately twice the accuracy rating. Slowly reset the reference potentiometer to the original value. Observe the instrument reading.

(6) Change the setting of the reference potentiometer until the instrument indication is less than the original value by an amount equal to approximately twice the accuracy rating. Slowly reset the reference potentiometer to the original value. Observe the instrument reading.

(7) Take the difference between the readings obtained in steps 5 and 6. This is the dead band and it should not exceed 0.10% of the scale span.

(8) Repeat the above procedure near the low and high ends of the scale.

Pointer Displacement Method—Proceed as follows:

(1) Rotate the drive cord pulley so that the measuring pointer travels approximately twice the accuracy rating above the balance position. Slowly release the pulley to keep the measuring pointer from overshooting the balance position. Observe the line drawn on the chart with the drive cord pulley fully released.

(2) Repeat step 1 above, rotating the drive cord pulley in the opposite direction.

(3) Take the difference between the lines drawn on the chart from steps 1 and 2 above. This is the dead band and it should not exceed 0.10% of the scale span.

FACTORY ADJUSTMENTS

These consist of the following, located on the respective cards as indicated:

(1) Input Card, Fig. J3 — Trimmer Capacitors

(2) Preamplifier, Fig. J4 — Frequency Adjust R7

(3) Amplifier, Fig. J5 — DC Current Offset Adjust R5
DC Voltage Offset Adjust R8
Damping Stability Adjust R30
Zero Amplifier Calibrate Adjust R33
Slidewire Amplifier Calibrate Adjust R38
Zero Offset Trim Adjust R42

The instrument comes with these controls factory set. Therefore, there should be no reason to readjust them unless inadvertently reset. The tests outlined below will indicate whether readjustment is actually required. All but R33, R38, and R42 are separately adjustable. These three, because of a certain amount of interaction between them, must be adjusted in a particular sequence as indicated. To get at the required points, where applicable, see Section K, General Test Information, Test Procedure.

Zero Check:

(1) Set the SPAN switch to V.

(2) Set the SPAN SET dial to 2.

(3) Short the input to the recorder.

(4) Turn the SPAN TRIM knob to the CAL (detent) position.

(5) Set the ZERO switch to OUT. The pointer should line up at zero (0) on the scale.

Span Check: Continuing from the Zero Check above—

(1) Remove the short from across the input.

(2) Apply 2 volts to the input terminals. The pointer should line up at 100% on the scale.

Range Check of Zero Suppression: Continuing from the Span Check above—

(1) Replace the short across the input terminals.

(2) Snap the ZERO switch to IN if uncalibrated or to (+) if calibrated.

(3) Turn the ZERO knob fully clockwise. The pointer should line up at 100% on the scale. If recorder performance is as indicated, R33, R38, and R42 are correctly set.

R8 Check:

(1) Short the input to the recorder.

(2) Set the ZERO switch to IN.

(3) Set the SPAN switch to V.

(4) Set the SPAN SET dial to 2.

(5) Adjust the ZERO knob for a pointer indication of 50% of scale.

(6) Turn the SPAN SET dial from 2 to 5.

(7) Observe the pointer. It should not move as the SPAN SET dial is reset from 2 to 5. If the pointer moves, readjust R8 until there is no such movement of the pointer.

R5 Check:

(1) Set the SPAN switch to V.

(2) Set the ZERO switch to IN.

(3) Adjust the ZERO knob for a pointer indication of 50% of scale.

(4) Substitute a 30 kilohm resistance for the short across the input terminals.

(5) Observe the pointer. It should not shift position as the resistance is interchanged with the short. If the pointer moves, readjust R5 until there is no such movement of the pointer.

R30 Check:

(1) Set the SPAN switch to V.

(2) Set the SPAN SET dial to .1 or insert a 100 mV span card.

(3) Set the ZERO switch to IN.

(4) Adjust the ZERO knob for a pointer indication of 50% of scale.

(5) With 45 millivolts connected to the input terminals from a reference potentiometer, alternately switch this voltage from +45 mV to -45mV. Damping should be critical, as observed by watching the pointer as the instrument balances. Use a fast chart speed if available for closer observation of the balancing action.

Adjust where necessary by first turning off power to the instrument. Remove the amplifier, make the adjustment, replace the amplifier, and then turn the power back on. Make adjustments in steps of two turns or less each time.

Resetting R33, R38, and R42—The following procedure outlines the proper sequence for resetting R33, R38, and R42. Also included are the setting of the converter trimmer capacitors, Fig. J3, and oscillator frequency via R7, Fig. J4. The other settings are assumed to be correctly set as indicated above. Also assumed to be set correctly is the scale, pointer, and pen lineup, in accordance with Section H, Scale, Pointer, and Pen Lineup.

(1) Using the drive cord pulley, move the pen carriage to the left end stop so that the penpoint lines up with the first line below the calibrated portion of the chart grid, and the pointer is on the dot below the first calibrated line on the scale.

(2) Connect a voltage source from a reference potentiometer (see Table H1) to the input terminals of the recorder and set the input to zero.

(3) Set the SPAN switch to V, SPAN SET dial to 1, SPAN TRIM to CAL (detent) position, or insert a 1 volt span card.

(4) Turn R38 fully counterclockwise; turn R42 and R33 fully clockwise. See Fig. J5.

(5) Set the ZERO switch to OUT.

(6) Apply a 1 volt input signal.

(7) Adjust R38 clockwise until the pointer indicates at 100% on the recorder scale.

(8) Reset the input source voltage to zero.

(9) Adjust R42 counterclockwise until the pointer indicates at zero on the recorder scale.

(10) Repeat steps 6, 7, 8, and 9.

(11) Reset the ZERO switch to IN.

(12) With zero input, turn the zero knob fully clockwise and observe

the scale reading, such as 94.

(13) Adjust R42 to move the pointer further downscale by the number of divisions that it already is below 100. That is, 100 - 94 = 6 divisions; set to 94 - 6 = 88. Continue readjusting R42 to move the pointer downscale two (2) more divisions, or down to 86.

(14) Adjust R33 to move the pointer to 100% on the scale.

(15) Reset the ZERO switch to OUT and observe the zero point. If it is not on zero, readjust R42 to move the pointer below zero by as much as it was above zero, or vice versa.

(16) Reset the ZERO switch to IN. Readjust R33 to move the pointer to 100% on the recorder scale.

(17) Connect a frequency counter to the chopper drive (pins 6 and 7 on the input card or pins 2 and 3 on the preamp). See Figs. J3 and J4.

(18) Adjust R7 on the preamp, Fig. J4, to set the frequency at 325 Hz ±2 Hz.

(19) Reset the SPAN switch to MV and the SPAN SET dial to .1, or insert a 100 microvolt span card.

(20) Reset the ZERO knob to move the pointer to 50% on the recorder scale.

(21) Connect an oscilloscope between TP1 of the preamp, Fig. J4, and ground.

(22) Adjust the FET trimmer capacitors, Fig. J3, to obtain minimum spike amplitude.

(23) Insert a 30 kilohm resistance in series with the input voltage source to the recorder. Readjust the trimmer capacitors to eliminate the effect of this resistance.

TROUBLESHOOTING WIRING

Typical schematic wiring of the AZAR and fixed-span circuits are shown in Fig. J6 and J7.

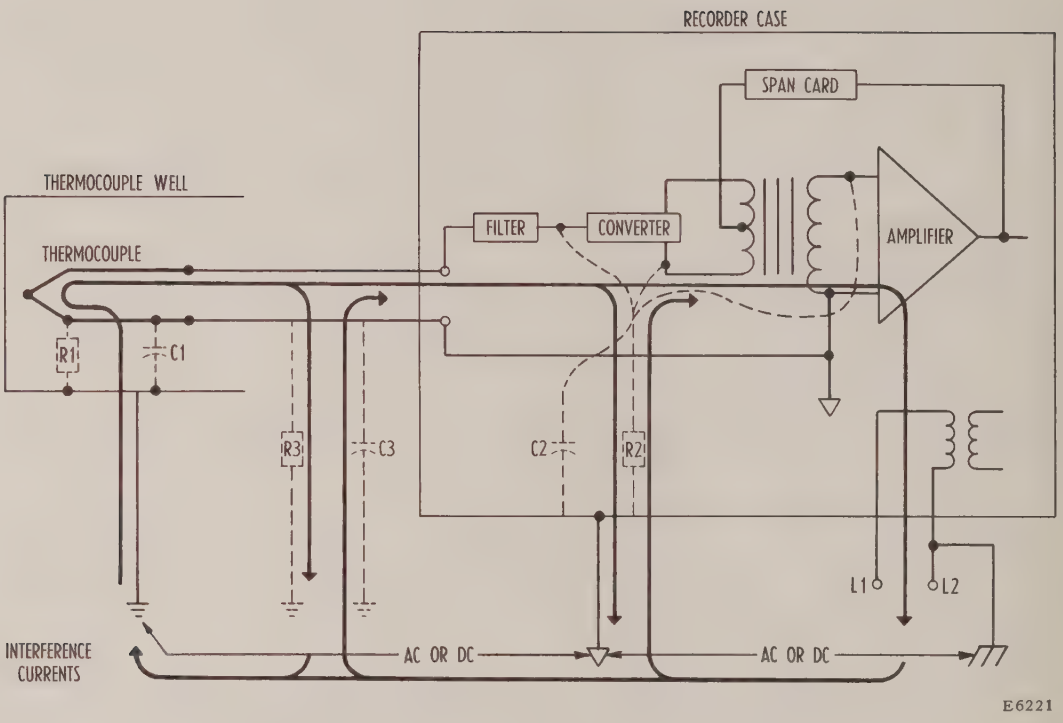


Fig. J1–Basic schematic of instrument showing typical leakage paths–both resistive and capacitive, to ground.

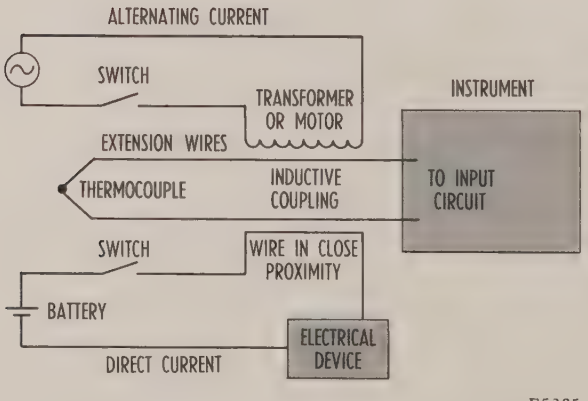


Fig. J2–Typical examples of inductive coupling.

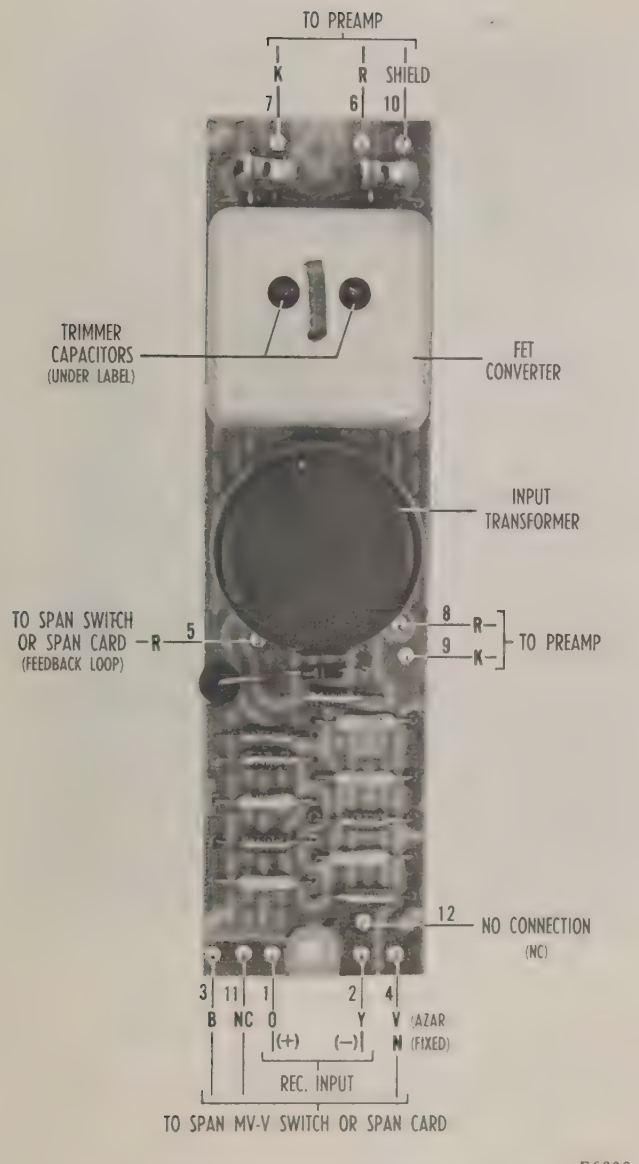


Fig. J3–444841 input card. See Fig. K1.

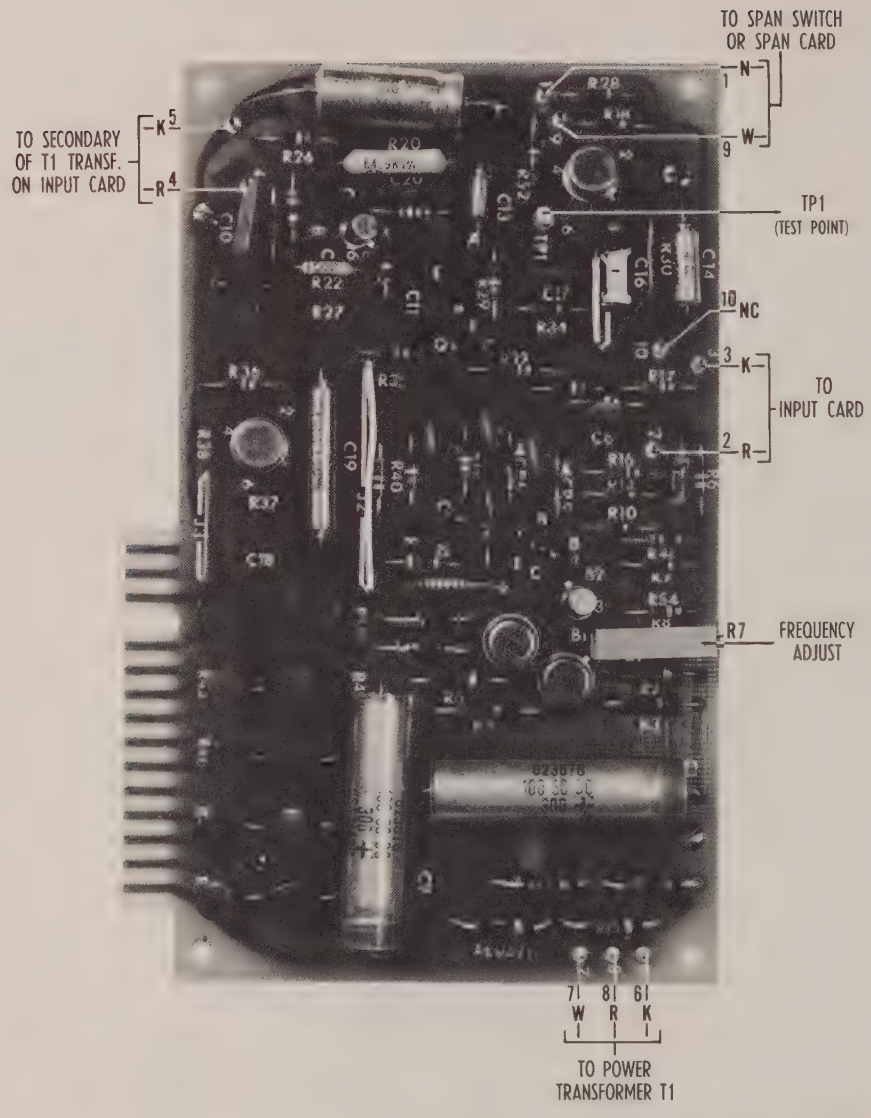


Fig. J4–444839 (AZAR) preamplifier. See Fig. K2.

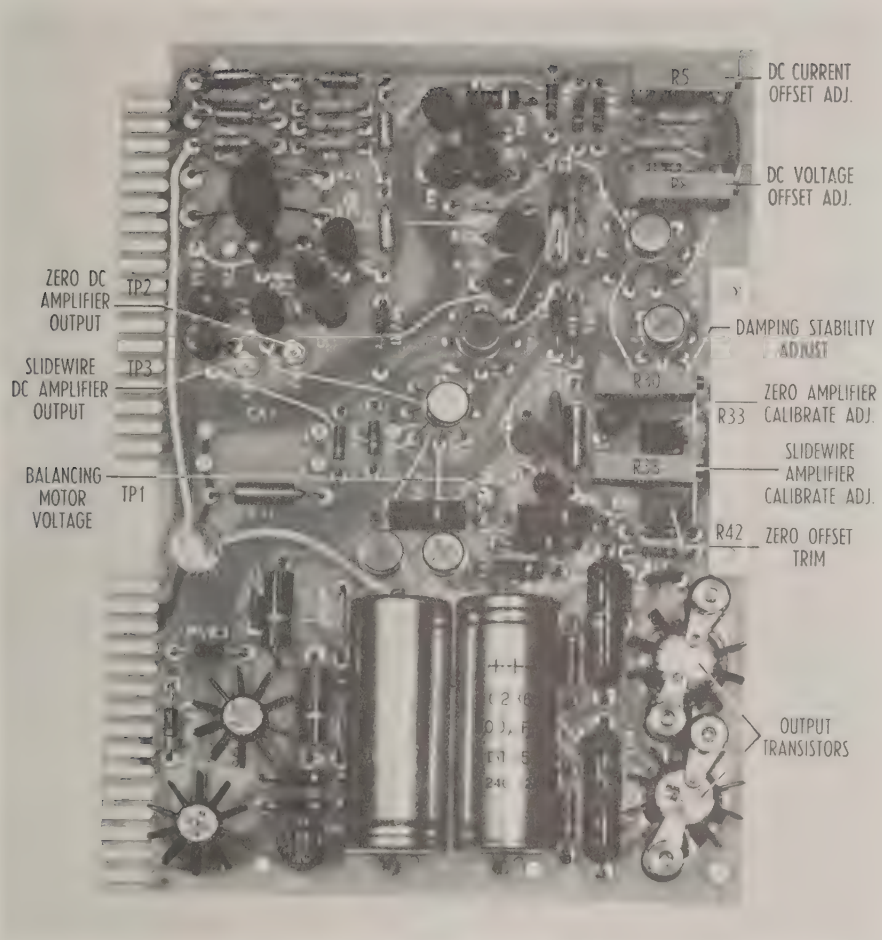
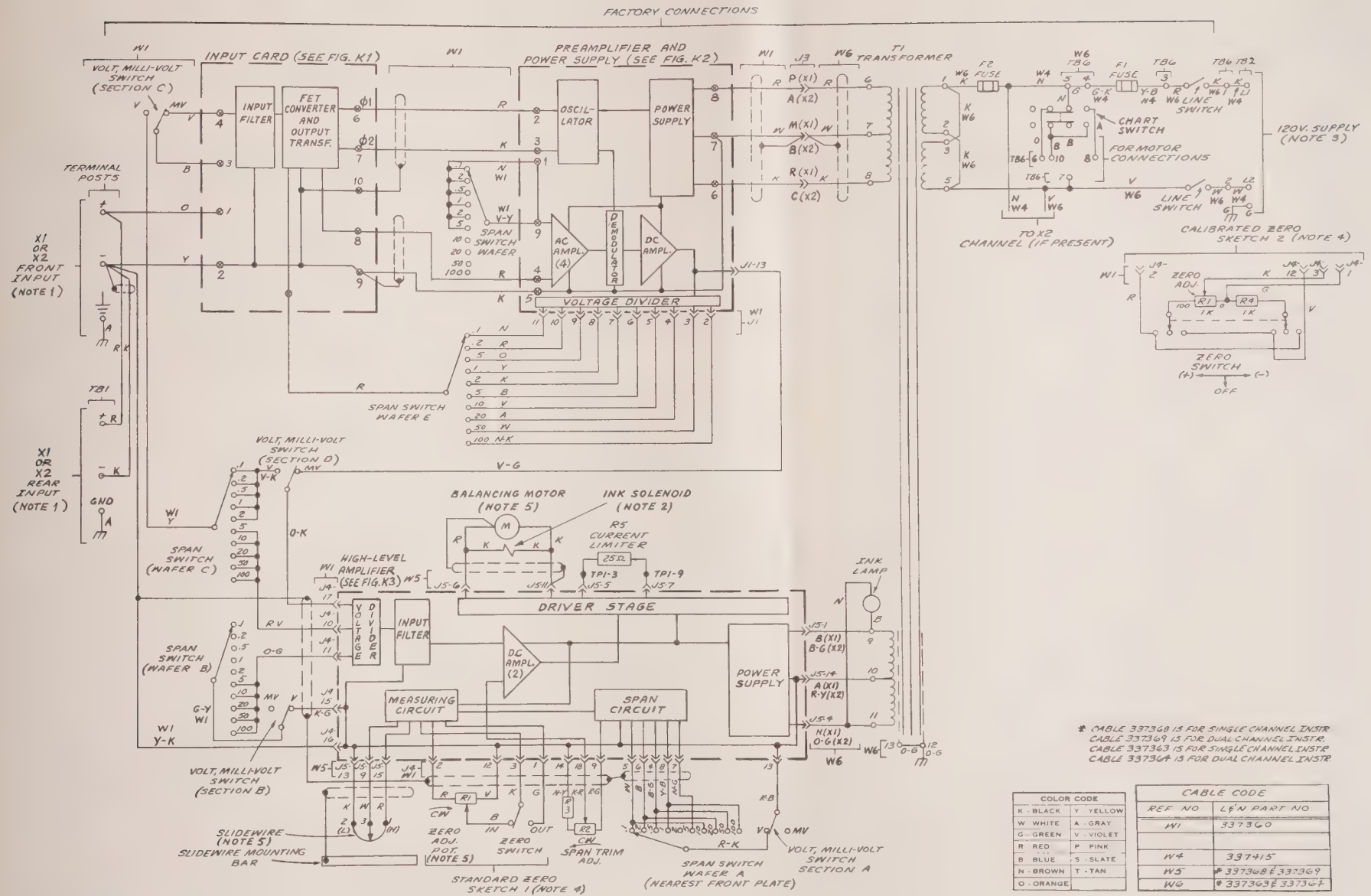


Fig. J5–444838 (AZAR) high-level amplifier. See Fig. K3.



* CABLE 337368 IS FOR SINGLE CHANNEL INSTR.
CABLE 337369 IS FOR DUAL CHANNEL INSTR.
CABLE 337363 IS FOR SINGLE CHANNEL INSTR.
CABLE 337364 IS FOR DUAL CHANNEL INSTR.

COLOR CODE	
K - BLACK	Y - YELLOW
W - WHITE	A - GRAY
G - GREEN	V - VIOLET
R - RED	P - PINK
B - BLUE	S - SLATE
N - BROWN	T - TAN
O - ORANGE	

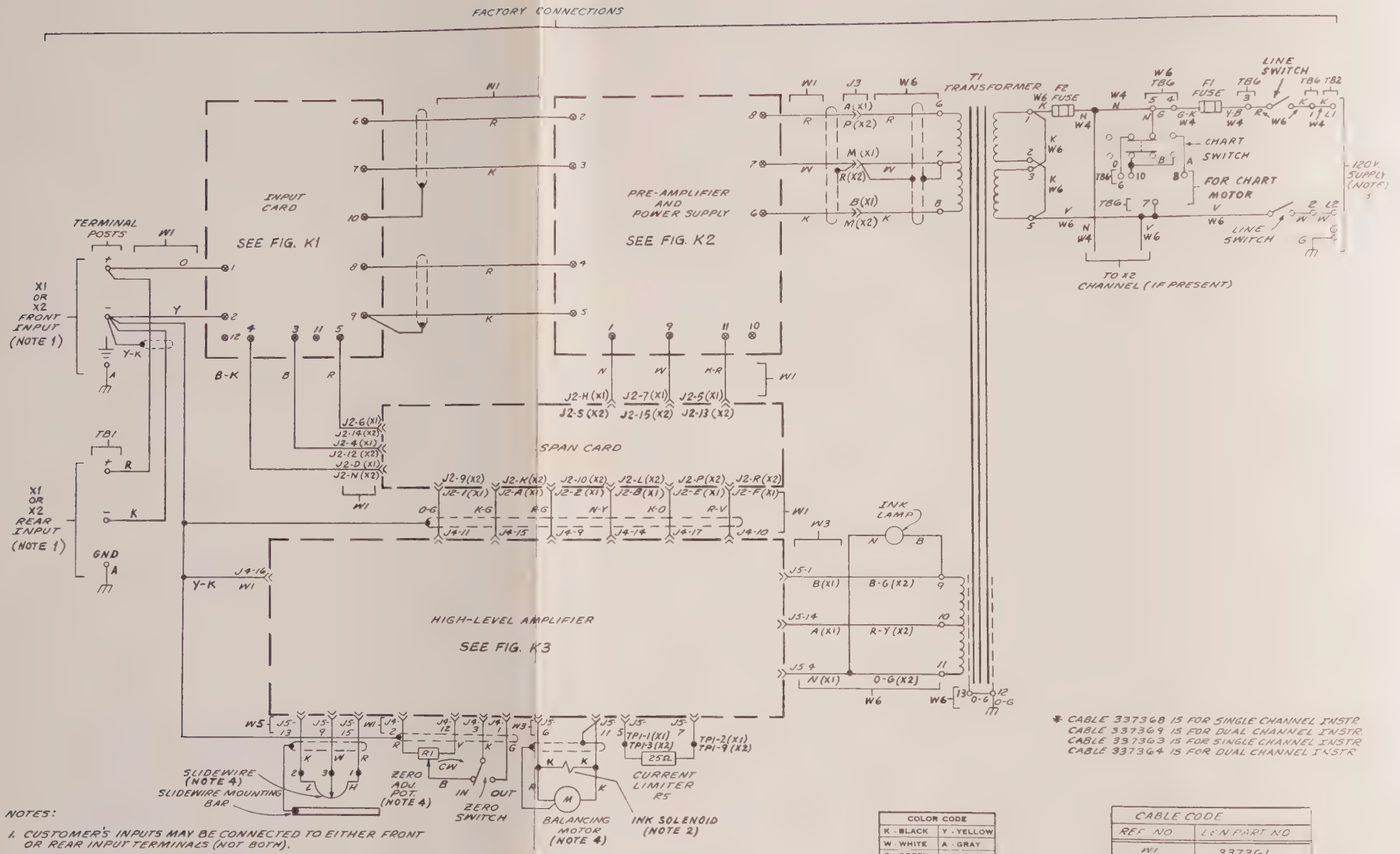
CABLE CODE	
REF NO	L&N PART NO
W1	337360
W4	337415
W5	* 337368 & 337369
W6	* 337363 & 337364

NOTES:

1. CUSTOMER'S INPUTS MAY BE CONNECTED TO EITHER FRONT OR REAR INPUT TERMINALS (NOT BOTH).
2. INK SOLENOID NOT SUPPLIED WITH ONE SECOND BALANCE.
3. L2 SIDE OF LINE SHOULD BE GROUNDED. IF LINE SUPPLY CANNOT BE GROUNDED, ADD ISOLATING TRANSFORMER AND GROUND.
4. FOR STANDARD ZERO, CONNECTIONS ARE MADE PER SKETCH 1. FOR CALIBRATED ZERO, CONNECTIONS ARE MADE PER SKETCH 2.
5. REVERSED RANGE: REVERSE RED "R" & BLACK "K" LEADS AT BALANCING MOTOR & SLIDEWIRE. ALSO REVERSE RED "R" & VIOLET "V" LEADS AT ZERO ADJ. POT.

DE6225

Fig. J6—Recorder schematic, with adjustable (AZAR) span.



NOTES:

1. CUSTOMER'S INPUTS MAY BE CONNECTED TO EITHER FRONT OR REAR INPUT TERMINALS (NOT BOTH).
2. INK SOLENOID NOT SUPPLIED WITH ONE SECOND BALANCE.
3. L2 SIDE OF LINE SHOULD BE GROUNDED. IF LINE SUPPLY CANNOT BE GROUNDED, ADD ISOLATING TRANSFORMER AND GROUND.
4. REVERSED RANGE: REVERSE RED "R" & BLACK "K" LEADS AT BALANCING MOTOR & SLIDEWIRE. ALSO REVERSE RED "R" & VIOLET "V" LEADS AT ZERO ADJ. POT.

COLOR CODE	
K - BLACK	Y - YELLOW
W - WHITE	A - GRAY
G - GREEN	V - VIOLET
R - RED	P - PINK
B - BLUE	S - SLATE
N - BROWN	T - TAN
O - ORANGE	

* CABLE 337368 IS FOR SINGLE CHANNEL INSTR.
CABLE 337369 IS FOR DUAL CHANNEL INSTR.
CABLE 337363 IS FOR SINGLE CHANNEL INSTR.
CABLE 337364 IS FOR DUAL CHANNEL INSTR.

CABLE CODE	
REF NO	L&N PART NO
W1	337361
W4	337415
W5	* 337368 & 337369
W6	* 337363 & 337364

Fig. J7–Recorder schematic, with fixed span.

DE6226

Section K–AMPLIFIER AND PREAMPLIFIER TROUBLESHOOTING

This section describes the testing and servicing procedures to be followed when the checks of Section J indicate amplifier or preamplifier trouble.

TEST EQUIPMENT

A volt-ohmmeter is required for checking ac and dc voltages and resistance values. It should have 20,000-ohms-per-volt impedance on the dc voltage ranges and 1000-ohms-per-volt impedance on the ac voltage ranges since the voltages given in this book are those obtained with a meter having these impedances. The Simpson Model 260 Multimeter has the required characteristics. If a lower impedance voltmeter is used in measuring voltages across high resistance circuits, lower readings must be expected, and conversely.

GENERAL TEST INFORMATION

Do not proceed with the tests of this section until the simple checks described in Section J have been carried out.

Exercise care in handling the printed-circuit modules by not attempting to flex them or to apply undue pressure to any of the mounted components; to do so may lead to intermittent or complete circuit failure.

Test Data—Test data given in this section is applicable to the 444841 input card, 444839 and 444896 preamps, and 444838 and 444897 amplifiers. See Figs. K1, K2, and K3. These drawings are the latest revisions at the time of printing. If differences exist between these and the actual units, make allowance for the differences.

Capacitor Testing—Capacitors of high value (0.1 μF and larger) are to be tested with the volt-ohmmeter set to its highest ohms range, or with a capacitor tester. When taking resistance readings across a capacitor or in any circuit where a capacitor is across the volt-ohmmeter the meter needle should deflect when first connected and then return to the value of resistance which may be involved in the circuit. This deflection indicates the capacitor is good and will take a charge. If the deflection does not occur, it will indicate that the capacitor is open-circuited and should be replaced. If the meter needle deflects and remains below the value of the parallel circuit resistance, the capacitor is short-circuited or is leaky and should be replaced.

> NOTE: If the capacitor is an electrolytic type, some leakage is to be expected. Also, the positive (+) ohmmeter lead must be connected to the positive side of the capacitor. Otherwise, the resistance reading will be low even if the capacitor is good.

On polarized tantalum capacitors, polarity should be observed. It should be understood that these capacitors can be damaged by reversing the leads of the ohmmeter.

Replacing Components—When a printed-circuit module has been found to be faulty, it should be replaced. Replacement of faulty parts on these modules is not recommended. If desired, faulty printed-circuit modules can be returned to Leeds & Northrup Company for repair. See Table F1 for the recommended spare parts to keep on hand for the number of functions in use.

When replacing chassis mounted components such as a faulty power transformer, the new part and wiring should conform to the original arrangement. For solder-connected items, use as little solder as possible when soldering but be sure a satisfactory connection is made.

Test Procedure—The extent of the testing to be done will determine what preliminary preparations must be made.

If the preamp or input card is to be tested, the instrument has to be partially disassembled in the following manner. This procedure can also be used for testing the amplifier or for resetting factory adjustments.

(1) With power turned off, release the latch and slide the input and recording modules to the extreme forward position.

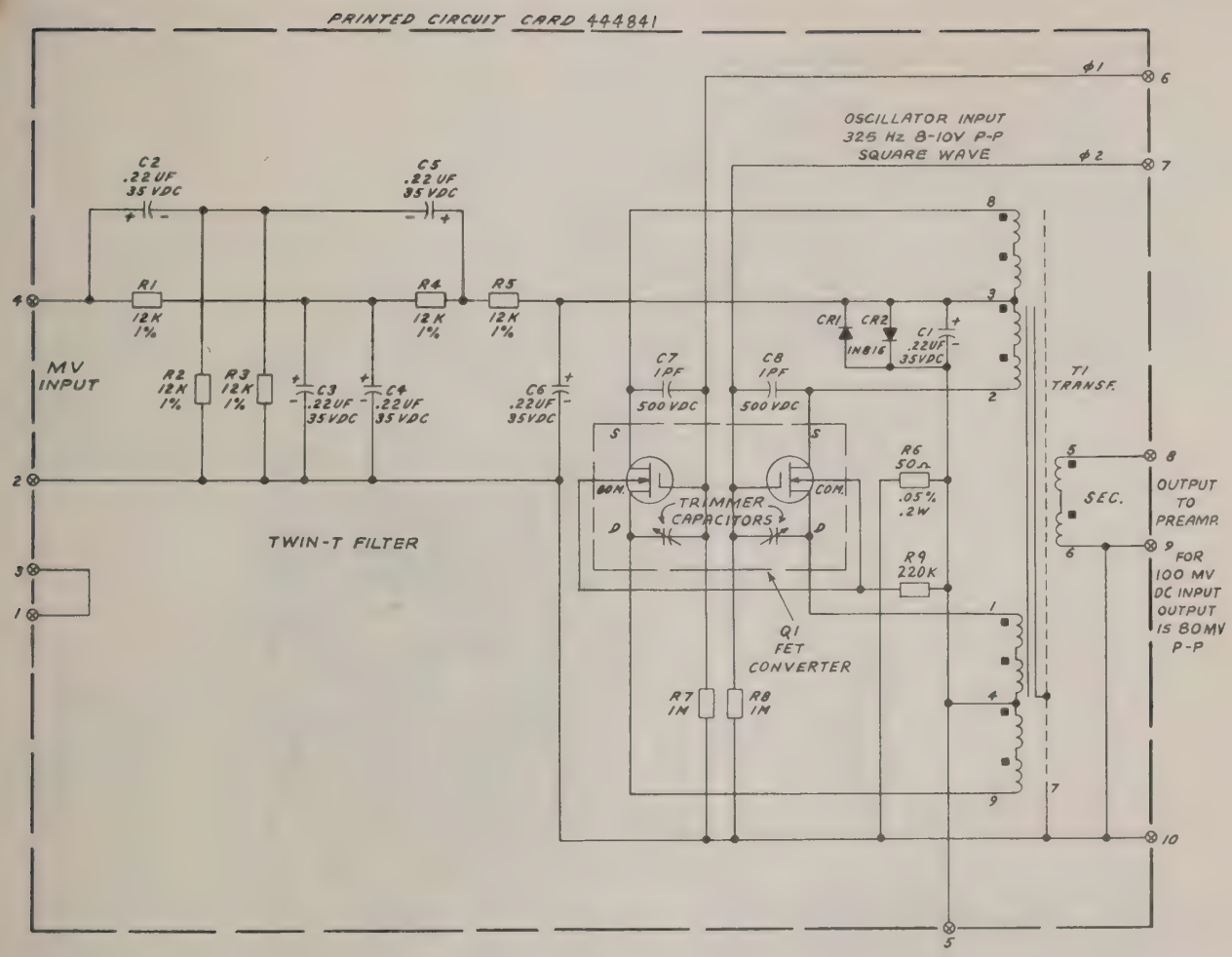
(2) Remove the mounting screws from the base platen and slide the entire recorder mechanism completely out of the case. See Fig. K4. Where wiring connections are made to the rear terminal board, also remove the two screws that hold this terminal board in position.

(3) Remove the mounting stud that holds the input module to the side of the recording module and take off the metal shields. Removal of the shields may cause some offsets on low millivolt spans.

(4) Loosen the high-level amplifier connector mounting screws and slide the amplifier(s) out the rear. Retain all electrical connections throughout, but insulate wherever necessary to prevent accidental shorting or grounding of exposed components or connections. See Fig. K5.

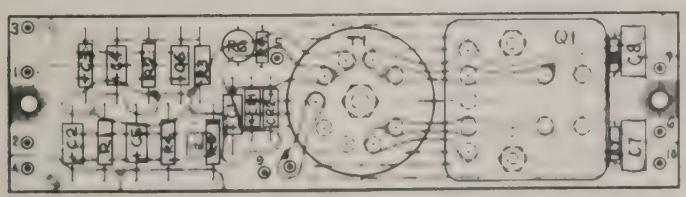
The voltage and waveform measurements are made at the points indicated in Figs. K1, K2, and K3. See also Figs. J6 and J7. For the waveforms an oscilloscope is required. Reference to the feedback loop in the waveform measurements of Fig. K2 means that the #5 pin connection on the input card, Fig. J3, is on (connected) for closed loop feedback and off (removed) for open loop feedback. A voltmeter is suitable for the other voltages shown but not for signal levels in the preamp because these levels are so small. Thus the suggestion that spares be kept on hand. Note, however, that spares must be of the same type. That is, a preamplifier or amplifier for a fixed span measuring circuit is not interchangeable with one for an AZAR measuring circuit and vice versa.

If the spare restores satisfactory recorder operation, it indicates that the replaced unit is faulty. If not, further checking of transformer voltages is in order.



NOTES:

1. UNLESS OTHERWISE SPECIFIED ALL RESISTORS ARE ¼W, 10%.



CE6227

Fig. K1–444841 input card schematic and actual.

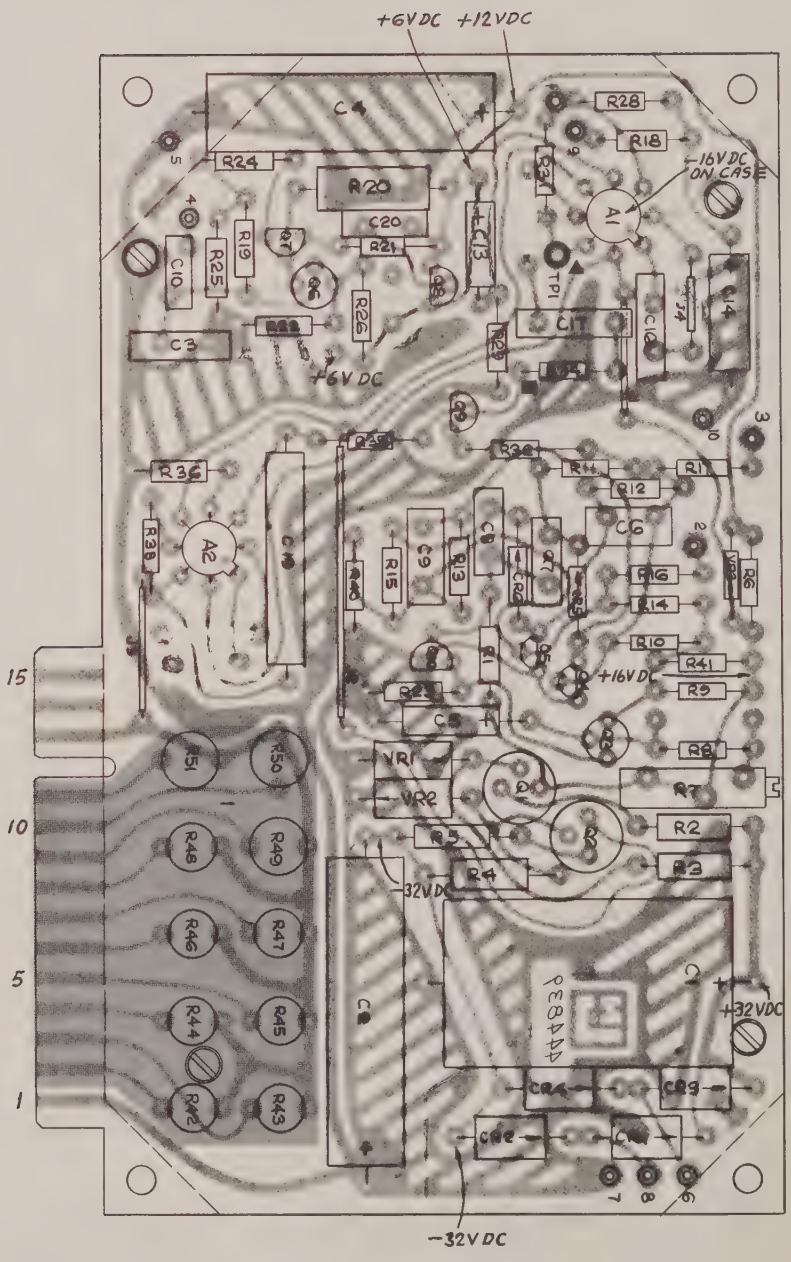
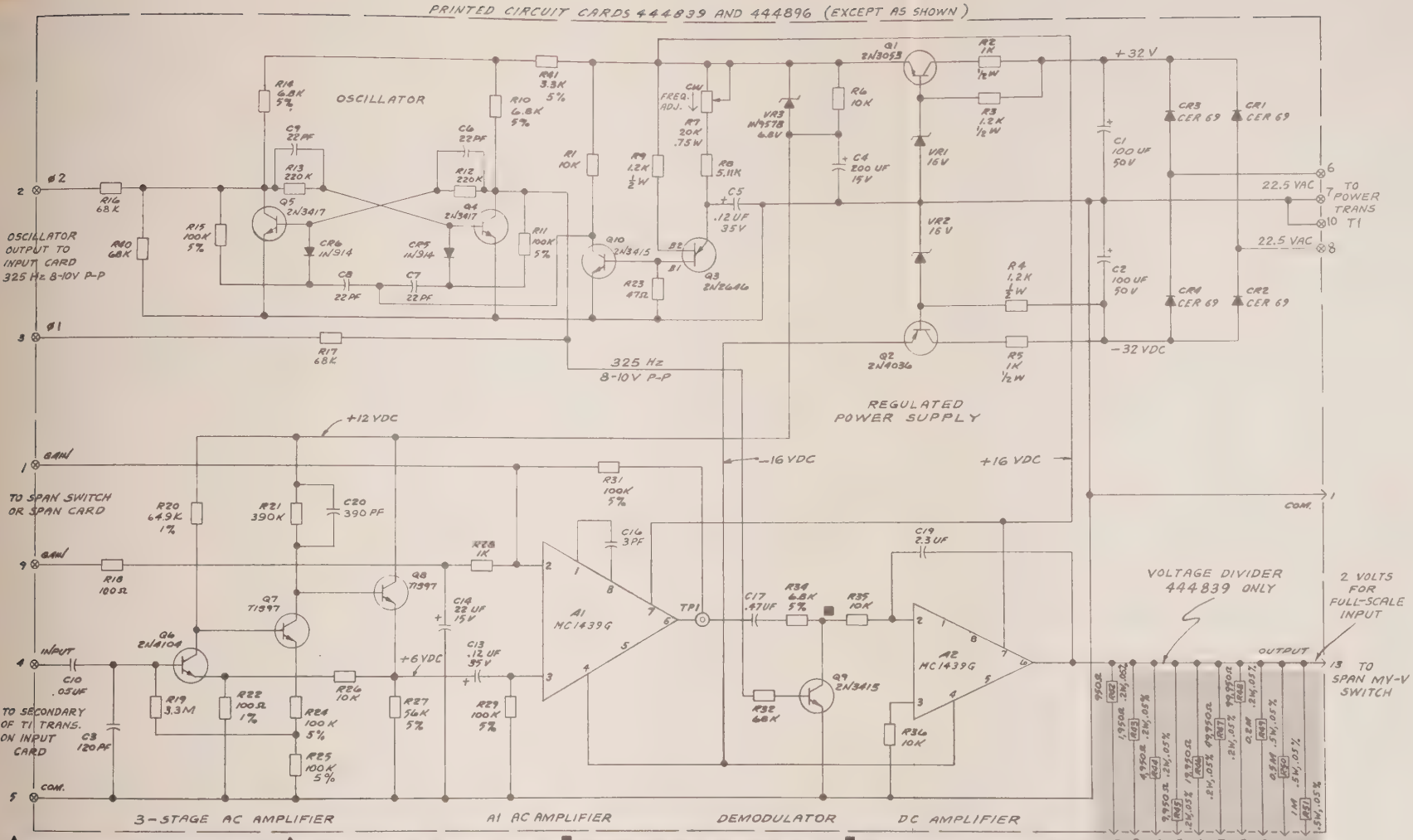
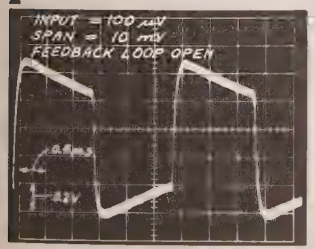
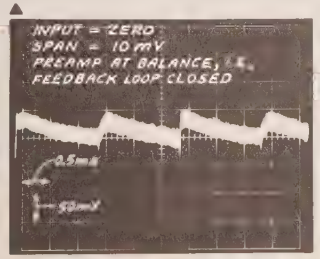


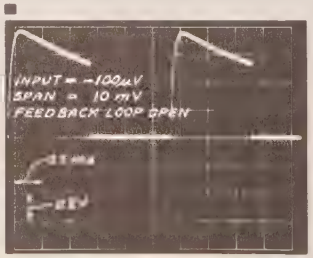
Fig. K2–444839 (AZAR) and 444896 (fixed span) preamplifier and power supply schematic and actual. Shaded area applies to 444839 and is the only difference between modules.

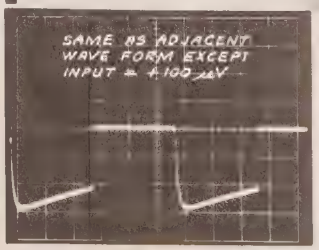
PRINTED CIRCUIT CARDS 444839 AND 444896 (EXCEPT AS SHOWN)











NOTE: GRIDS ARE 1 CM SQUARE

UNLESS OTHERWISE SPECIFIED, ALL RESISTORS ARE $\frac{1}{4}$W, 10%
DC VOLTAGES MEASURED WITH RESPECT TO CIRCUIT COMMON

EE6228

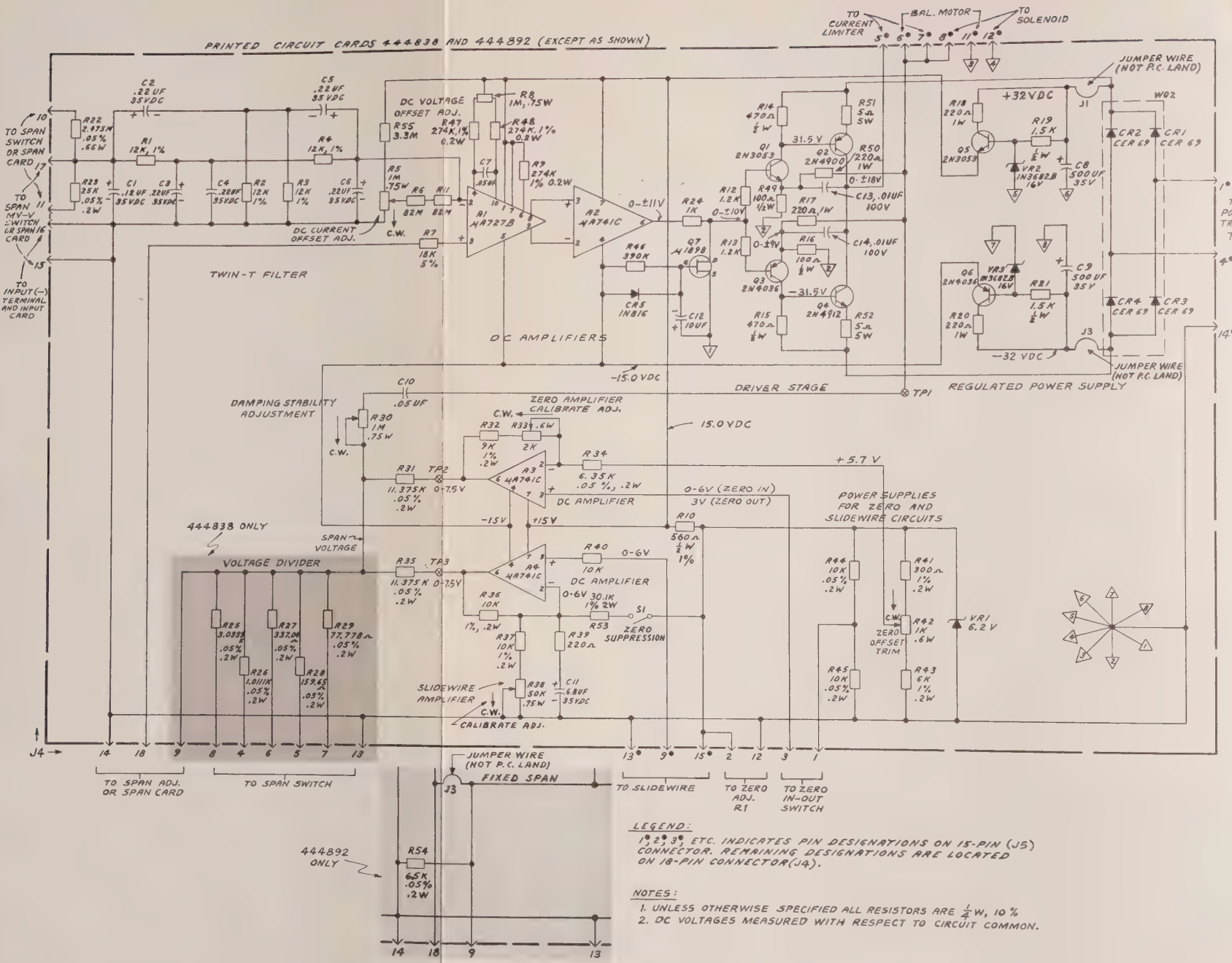
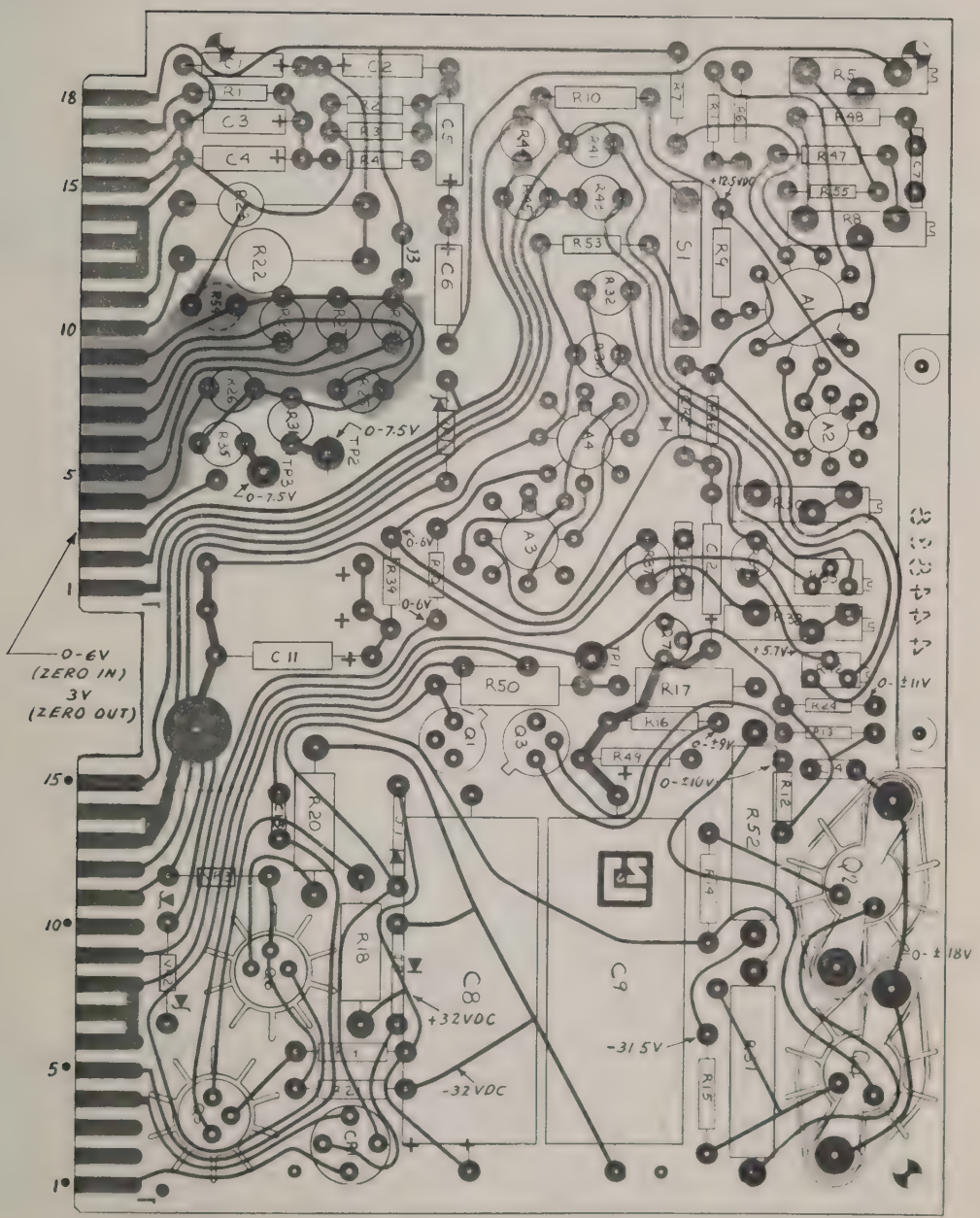
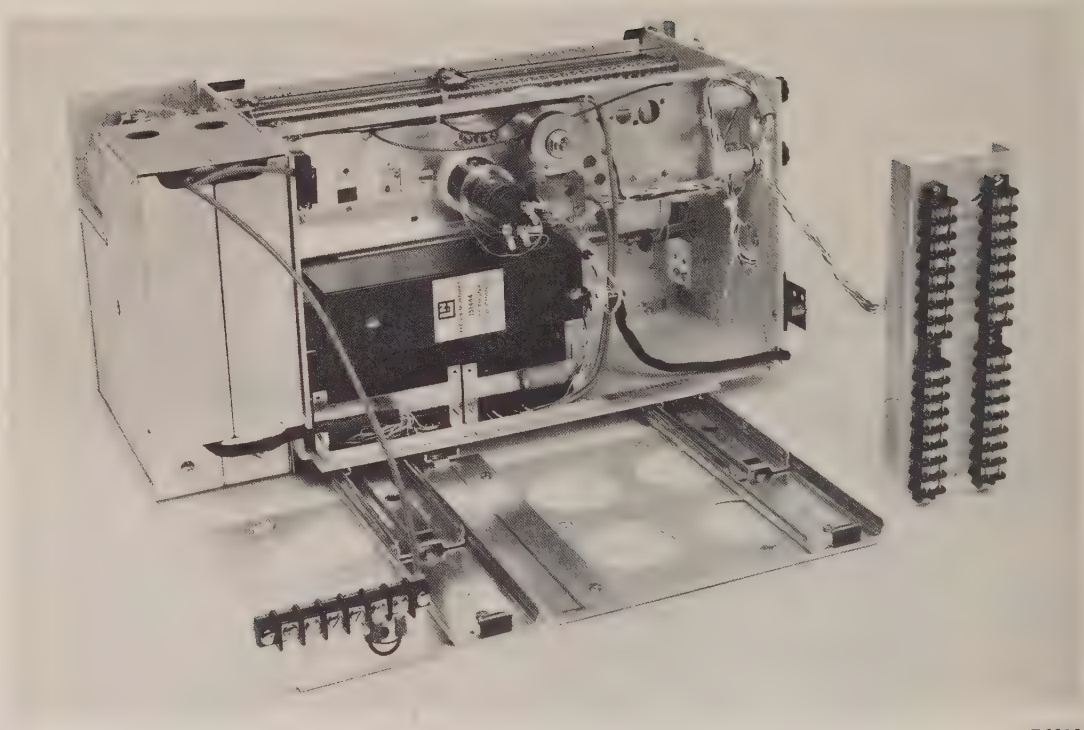


Fig. K3—444838 (AZAR) and 444892 (fixed span) high-level amplifier schematic and actual. Shaded areas apply to respective amplifier as noted.

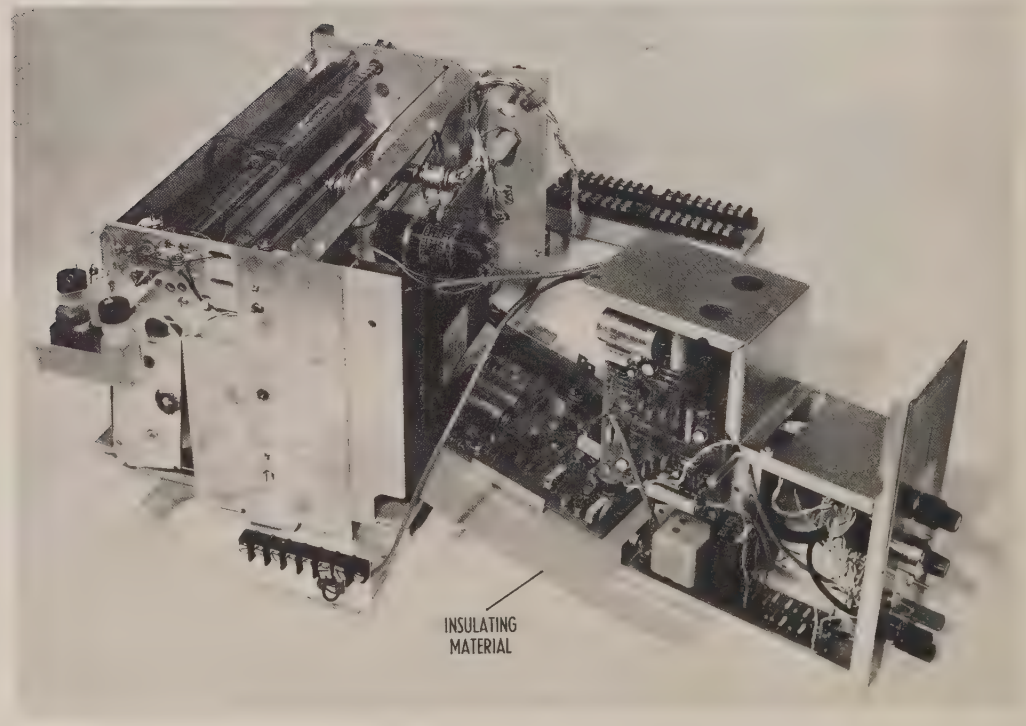

0-6V
(ZERO IN)
3V
(ZERO OUT)
0-7.5V
0-7.5V
0-6V
0-6V
+12.5VDC
+5.7V
0-±11V
0-±9V
0-±10V
0-±18V
+32VDC
-32VDC
-31.5V
C1
C2
C3
C4
C5
C6
C8
C9
C11
R1
R2
R3
R4
R5
R8
R9
R10
R17
R18
R20
R22
R35
R47
R48
R50
R52
R53
R55
S1
TP1
TP2
TP3
Q1
Q2
Q3
A1
A2
A3
A4

EE6229



E6230

Fig. K4–Recorder shown removed from case.



E6231

Fig. K5–Recorder shown removed from case for testing, or resetting of factory adjustments.

PART III TECHNICAL INFORMATION

Section L-NULL BALANCE MEASURING SYSTEMS

PRINCIPLES

The Speedomax XL instrument has one or two automatic null-balance measuring systems in which balance in each system is accomplished through the use of electronic amplifiers, one of which is a preamplifier. The essential parts of each such system are, (1) the null-balance measuring circuit, (2) the null detector-amplifier, (3) the balancing motor and linkage, and (4) the display system, i.e., recording and indicating devices.

Fig. L1 illustrates the general plan of a system. In this instance—measurement of emf—the measuring circuit consists of an adjustable calibrated emf connected to oppose the emf developed by the preamp output. If these two emf's are not equal, an "error" or unbalance current flows as shown and is detected by the preamp or amplifier.

After amplification, the error signal is applied to the reversible balancing motor which then works through the mechanical linkage to adjust the calibrated emf. The system is sensitive to the direction of error current so that the motor always adjusts the calibrated emf in the proper direction to reduce the magnitude of the error current. The motor continues to drive until the error current no longer produces motor rotation. A null or balance condition then exists.

While adjusting the calibrated emf, the motor also drives the display system. Pointer position and also pen position therefore directly indicate the calibrated emf and hence the emf being measured. The indicator scale may be marked in terms of emf, or in terms of temperature or other variable producing the measured emf.

SUMMARY DESCRIPTION OF CIRCUIT OPERATION

Fig. L2 is a functional block diagram of the recorder. A dc input signal of 100 microvolts to 100 millivolts is connected to a twin-T filter where it is converted to ac via a 325 hertz FET full-wave switching converter which receives its driving signal from an oscillator. The signal is transformer coupled to three separate ac transistor stages and ac amplifier A1. After which it is demodulated and dc amplified by amplifier A2. Here it becomes the preamp output and is two volts for full-scale input. This output appears across a voltage divider in the amplifier input, a portion of which is fed back to the input transformer, equal in magnitude and polarity to the unknown dc millivoltage originating at the recorder input.

For small signal levels—SPAN switch in the MV position—the output of the preamp becomes the input to the amplifier. For larger signal levels—SPAN switch in the V position—the input to the amplifier is 10%

millivolts to 100 volts dc and the preamp is bypassed. Here again, the input is connected through a twin-T filter, then through dc amplifiers A1 and A2 and a final driver stage that applies plus or minus 3 to approximately 24 volts dc to the servo motor. This output is offset by the slidewire and zero amplifier outputs and appears as a voltage feedback, equal in magnitude and polarity to the unknown dc voltage originating at the recorder input or preamp output.

THERMOCOUPLE REFERENCE JUNCTION MODULES

For thermocouple inputs a separately supplied reference junction is required. Two types are available, one with self-powered mercury cell, the other for line operation. The mercury cell unit is shown in Fig. L3. Jacks at the rear plug directly into the recorder input terminals. The thermocouple extension wires connect to terminals on the front. An on-off switch, also located on the front, must be actuated when the thermocouple measurements are actually being made. The mercury cell is good for 2500 hours of continuous operation or up to two years on intermittent duty. Dimensions are 2-9/16" long (excluding terminals), 2" wide, and 1-9/16" high. See Fig. L3. Accuracy is ± 1/4°C for 0° reference in 20-30°C ambient range with base metal thermocouples.

The line-operated unit plugs into a 120 volt, 60 Hz supply and is suitable for continuous operation. It can be bench or wall mounted. Connections to both thermocouple and recorder are made at one end via screw terminals. Dimensions are 5-3/16" long by 4" wide by 3-1/16" high. Accuracy is ± 1/4°C for base metal thermocouples.

Each different thermocouple to be used with the instrument requires a separate reference junction unit for that thermocouple. The units are available for all standard type couples, i.e., types K, T, J, S, and R, as well as many of the more exotic types.

When the recorder is supplied for use with thermocouple, the range is in terms of millivolts only. That is, the span card is calibrated in millivolts which are the equivalent of the thermocouple range to be covered. For example, the emf span for a temperature range of 0-500°C for an IC couple would be 27.39 millivolts.

For AZAR equipped input modules, this signifies that the range of any thermocouple can be set up by means of the AZAR controls alone, provided a reference junction unit is also used.

The Thermocouple—For electrical measurement of temperature, the thermocouple is the most frequently used primary element. A thermocouple consists of two dissimilar metal wires joined together by twisting, compression, welding, etc., to form a measuring or "hot" junction at one end. The opposite ends of the thermocouple wires are connected to the reference junction unit and then in turn to the instrument which measures the output emf of the couple. Fig. L4 shows this arrangement for a thermocouple composed of iron and Constantan (a copper-nickel alloy).

Temperature is measured by inserting the hot junction T1 into the medium to be measured and keeping the cold or reference junction T2 at a fixed temperature. A measureable emf is produced, with a value depending on the relative values of T1 and T2 (Fig. L4).

If the emf is to be reliable indication of the temperature of T1, the cold junction temperature T2 must be kept constant or a compensating feature must be introduced to nullify a change in T2. By maintaining the junction of the thermocouple and copper leads (cold junction) at a constant temperature, thermal emf error at the cold junction is constant and can be calibrated out. This is the purpose of the reference junction unit.

Theory of Operation—Fig. L5 shows the basic bridge circuit and thermocouples which function as an integral unit producing any desired, factory preset, reference temperature. R2 is a temperature sensitive component thermally bonded to the cold junction thermocouples. The resistance-temperature curve of R2 matches the emf-temperature curve (as tabulated by the National Bureau of Standards) of the thermocouple material. The voltage change across R2 is equal and opposite to the cold junction thermal voltage change over a wide ambient temperature range, resulting in virtually error-free compensation. The ratio R4/R3 + R4 is factory adjusted to produce an offset voltage equal to the required reference temperature, usually 0°C.

The accuracy of this solid-state type of reference junction is ±.3°C; typical long-term stability is ±5μV. Because it is a passive bridge circuit and is energized from an external regulated source, it requires no warmup time. Since it does not spark or arc, it can be used in an explosive atmosphere. Typical power consumption is about 250μW.

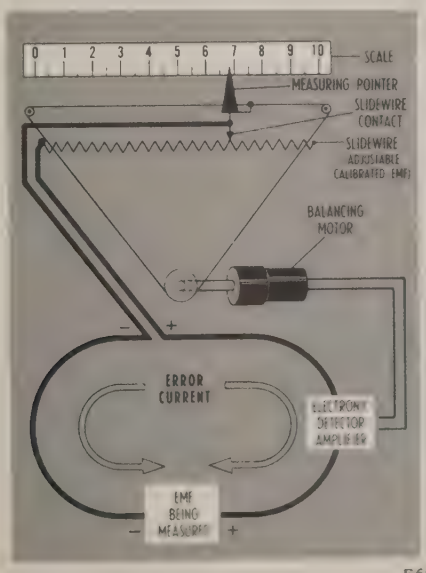
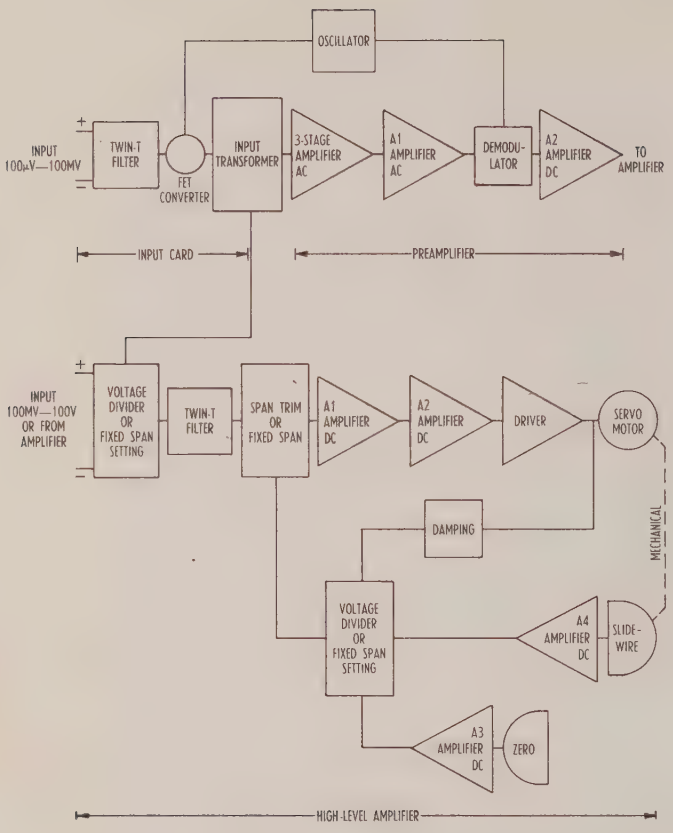
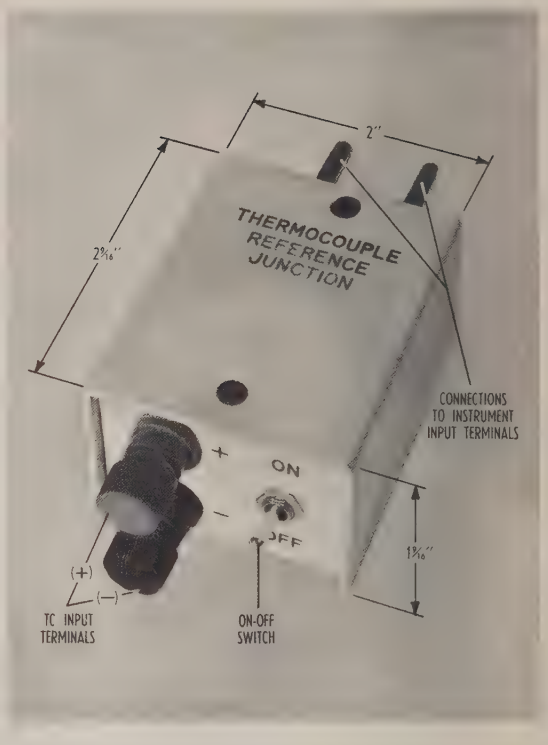


Fig. L1–Schematic illustration of null-balance emf measurement.



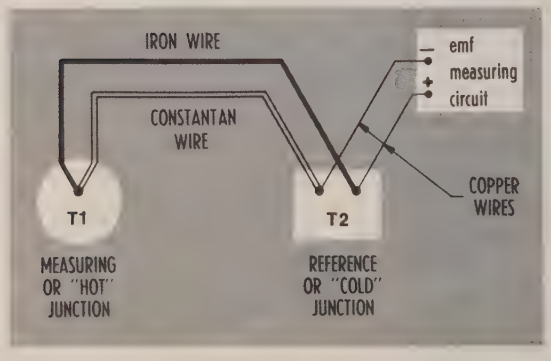
E6232

Fig. L2-Functional block diagram of Speedomax XL, 600 Series recorder.



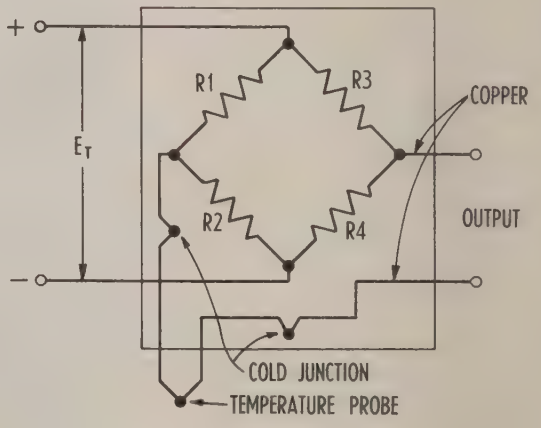
E6073

Fig. L3-Thermocouple self-powered plug-in reference junction unit.



E6074

Fig. L4-Basic thermocouple circuit.



E6075

Fig. L5-Basic bridge circuit and thermocouples.

Section M–TWO-POSITION CONTROL

Two-position control, also called "on-off" or "open-shut" control, is the simplest type of automatic control, and is suitable for many processes where the control requirements are not critical. It gets its name from the fact that the device which regulates the process input, e.g., a fuel valve in the case of a heating process, can assume only two positions regardless of the value of the variable being controlled. In two-position control, the process input is automatically set to one limit when the controlled variable falls below a predetermined level, and is automatically set to the other limit when the controlled variable rises above a predetermined level.

The switches on the Speedomax instrument can be used to provide two-position control of the variable being measured. The switches may operate a valve, contactor, damper, or other device controlling the process input.

Depending upon the user's needs, the two-position control may be of either the single point or the differential-gap type as follows:

TWO-POSITION SINGLE POINT CONTROL

In this arrangement, the process input is changed from maximum to minimum and from minimum to maximum at the same value of the controlled variable. Fig. M1 illustrates this control action in the case of a temperature control. Here it is assumed that a single low contact is used to turn on a heating element whenever temperature falls below the set point, and to turn off the element when temperature exceeds the set point.

In any process there is some delay or lag between a change in the input and the resultant change in controlled variable indicated on the measuring instrument. Consequently, as shown in Fig. M1, when heat is turned on, temperature continues to fall for a period before starting to increase. Similarly, when heat goes off, temperature continues to rise for a period before starting to decrease. This alternate overshoot and undershoot of the set point produces the cyclic temperature fluctuation shown. Such cycling is an inherent characteristic of two-position control.

The magnitude of the cyclic temperature swings, and hence the magnitude of the deviations from the set point, is directly related to the heat transfer characteristics and measuring lags of the particular process. Thus if the temperature measurement responds rapidly to changes in heat input, departure from the set point will be small. Conversely, where response is slow, substantial temperature deviations will result. This dependence of the control behavior upon process lags applies not just to heating processes, but to any type of process.

Fig. M2 illustrates the effect of process demand on two-position

control. Curve (1) shows the same condition as Fig. M1; that is, temperature cycles evenly about the set point, heater on and off times being equal. For a higher process demand, i.e., more heat required to maintain a given temperature, the response is as shown by curve (2). Here the on time is greater, while the temperature cycles at a lower average value than in curve (1). Curve (3) shows these effects reversed for a lower process demand. In general, the ratio of on-time to off-time is proportional to demand, and the average is above or below the set point.

TWO-POSITION DIFFERENTIAL-GAP CONTROL

In this method of control, the process input is changed from maximum to minimum at one value of the controlled variable and from minimum to maximum at another value of the controlled variable. Fig. M4 is a schematic diagram of such a control arrangement. As shown, two switches are used, but only the low contact of each switch is connected into the circuit. These contacts operate auxiliary relay R which in turn controls the process input.

Switches No. 1 and No. 2 are set to operate at equal deviations of instrument reading below and above the set point, respectively. The difference between these two switch settings, measured in terms of scale units, is the differential gap.

Assume that the arrangement shown in Fig. M4 is to be used for controlling an electric heating process. Then the heater contactor coil is connected in series with the SR-2 front contact. When process temperature is below the setting of both switches, relay SR is energized and the SR-2 front contact is pulled in to turn heat on. At the same time, the SR-1 front contact is also closed. Thus relay SR is kept energized through its own SR-1 front contact and the L contact of switch No. 2, and heat remains on even after increasing temperature causes the L contact of switch No. 1 to open.

When temperature rises to the setting of switch No. 2, its L contact opens, thereby de-energizing the SR relay coil. This drops out the SR-2 front contact, turning heat off, and also opens the SR-1 front contact. The heat then remains off until decreasing temperature again operates switch No. 1, thus starting a new cycle.

Fig. M3 illustrates the control action provided by this circuit. It can be seen that the response is nearly identical with that of the single point control shown in Fig. M1. Because of the differential gap, it differs in two respects: (1) the magnitude of the cyclic temperature swings is greater, and (2) operation of the final control element (the contactor in this instance) is less frequent. In some applications where the final control element is a valve or power contactor, this reduced frequency of operation may be particularly desirable, and usually is the principal reason for using differential-gap control, despite the corresponding increase in deviation from the set point.

In the preceding example, it was required to energize the final control element, i.e., the contactor, for low values of the measured variable. In some arrangements, however, reversed control action might be required, i.e., final control element energized for high-instrument readings. This is done by connecting the final control element in series with the SR-2 back contact, Fig. M4.

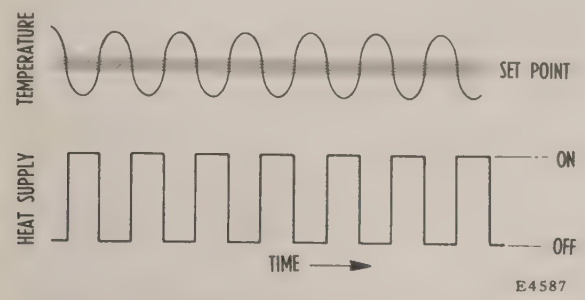


Fig. M1–Two-position single point control action.

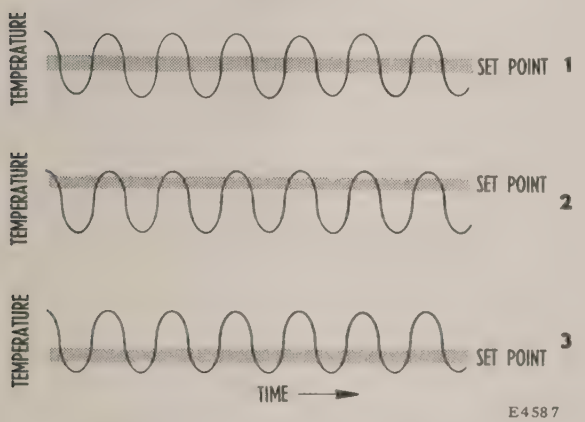


Fig. M2–Effect of process demand on two-position control action.

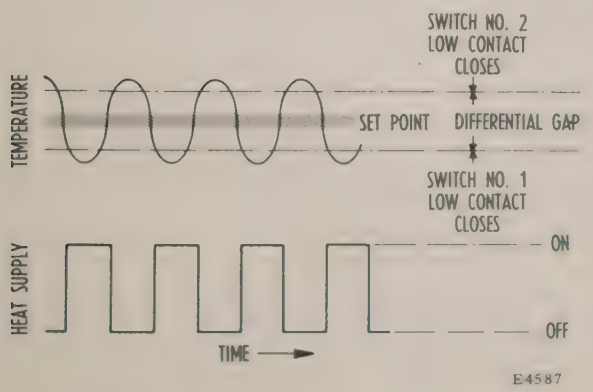


Fig. M3–Two-position differential gap control action.

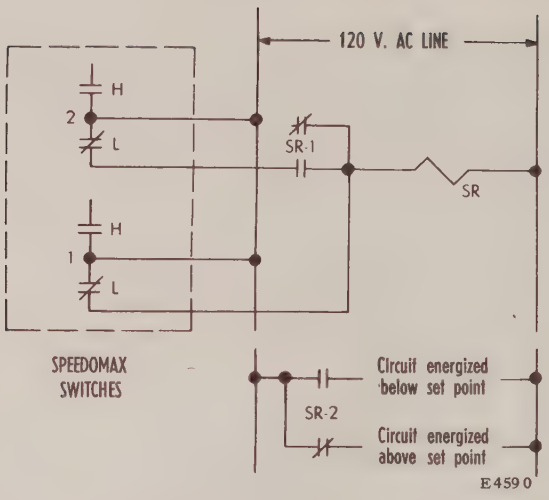


Fig. M4–Schematic of two-position differential gap control circuit using two switches and an auxiliary relay.

PART IV APPENDIX

Section N–FIELD CHANGES AND OPTIONAL FEATURES

SPAN CHANGE

On those instruments furnished with span cards, the instrument span can easily be changed to a new one. Simply slide out the input and recording modules, remove the existing span card and replace with one having the desired span. The connector is polarized so that insertion can be made in the correct manner only.

After making the span card change, it is advisable to recheck the calibration of the instrument as instructed in Section H.

REVERSED RANGES

In general, ranges that cause the pointer of an instrument to be driven upscale (from left to right) as the input variable becomes more positive are known as standard ranges. Reversed ranges are just the opposite. They cause the pointer to be driven upscale as the input variable becomes less positive (more negative). Examples of reversed ranges are +10 to 0, -10 to -20, etc.

An instrument furnished with a reversed range has the same measuring and motor circuits as an instrument with a standard range. Therefore, any standard instrument can be converted from standard range to reversed range and vice versa.

For example, to convert a standard range to a reversed range: 1) Reverse the connections to the balancing motor; 2) Reverse the connections to the low (L) and high (H) ends of the measuring slidewire; 3) Optionally, reverse the connections to the ZERO potentiometer on the input module. Making this change will cause upscale motion for clockwise rotation and downscale motion for counterclockwise rotation. If this change is not made, clockwise rotation of the ZERO knob will cause downscale motion and vice versa. Then recalibrate the recorder.

Note that when removing the snap-off connectors from the slidewire, exert a downward force on the slidewire near the pin terminals to avoid pulling the slidewire from its mounting support. Also, a new scale may be required unless the one presently in use can be appropriately re-marked.

CHART SPEED CHANGE

Several different chart speeds are available—from 1 in./hr. to 480 in./hr. To change to a different chart speed, simply replace the chart motor in use with the desired type. See Section F, Motors, Chart Motor(s).

In addition to a maximum of two single chart speeds, a 10-speed electronic chart drive unit is also available. This unit covers speeds from 4 to 480 in./hr.

OTHER OPTIONAL FEATURES

These features are covered in separate directions or in drawings supplied with the instrument, where applicable. Some other features available, besides those already described, include:

(a) Event marker pen.
(b) Adapter for rack mounting.
(c) Panel mounted case.
(d) Nonstandard scales.
(e) One-second span-step response time.

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CA, San Francisco (San Mateo)
CO, Denver
CT, Hartford (West Hartford)
DE, Wilmington
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FL, Orlando
GA, Atlanta
IL, Chicago (Rosemont)
IL, Lansing
IN, Indianapolis
IA, Davenport (Bettendorf)
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